WORLD

animal

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33

COMMENT

The water buffalo

For many years FAO has emphasized the present value and even greater potential value in the future of the water buffalo (*Bubalus bubalis*). It has endeavoured to stimulate interest in this neglected domestic animal and has stressed the need for much more research in order to obtain a better understanding of it.

With the assistance of Australia's Freedom from Hunger Campaign, FAO published in 1974 *The husbandry and health of the domestic buffalo.* This book brought together much of the available knowledge on the water buffalo and provided a comprehensive review of its position in those countries in which it is of importance. Two further publications from the same source followed, *The buffaloes of China* and *The water buffalo* — the latter an abridged edition of the first book mentioned.

The water buffalo is now found in some 40 countries including Bulgaria, Greece, Italy, Egypt, Iran, Iraq, the countries of the Indian subcontinent, China and Southeast Asia. It is also found in Trinidad, Hong Kong, the Northern Territory of Australia and the Amazon Valley of South America.

The water buffalo exists in greatest numbers in areas of the world where shortage of protein, especially animal protein, is most acute. Its importance as a source of milk has long been recognized and no one doubts its great potential for meat production. Over the years it has constituted one of the world's major sources of farm power. In spite of past neglect buffaloes are steadily increasing in numbers in most countries where they are found.

The improvement of the water buffalo could yield spectacular results if the methods of selective breeding, used in the case of the modern, high-producing breeds of dairy cattle, were to be utilized for buffaloes maintained under good conditions of nutrition and health. This is especially so in India and Pakistan where extensive genetic variation is present.

The main constraints against the improvement of buffalo productivity are the inadequacies of both research and the testing and demonstration of research results in the field, the lack of effective extension efforts, and the generally low level of development of the countries where the buffalo is found. The principal owners and users of buffaloes are small-scale farmers who lack resources, and it is for this group that research now urgently needs to be undertaken.

Countries such as Egypt, India, Indonesia, Pakistan, Philippines, Sri Lanka and Thailand are already devoting resources to buffalo research. In some cases these efforts are being strengthened by international aid as, for example, in the Philippines where an FAO/UNDP project for strengthening the Philippine Carabao Research and Development Centre has recently been approved. In the Asia, Far East and Southwest Pacific Region, however, there is general agreement among the countries concerned that further investment is required in a properly coordinated research programme.

Fields in which research is now urgently needed include the better utilization of crop residues such as straw (mainly fed to buffaloes by the small farmer) and their supplementation in the ration; the incorporation of various locally available agricultural and agro-industrial by-products into the feeding system, and feed evaluation. A number of specific problems characterize buffalo reproduction; how these can be overcome needs to be the subject of further research as soon as possible. International testing of buffalo breeds and strains in different countries to determine their relative genetic merits in order to meet the need for proven sires, and as the basis for global breed improvement programmes, also urgently needs to be undertaken.

As a result of the growing awareness of the economic importance of the water buffalo and because of numerous requests for international support for its improvement, various alternative means of implementing a comprehensive programme of buffalo research have been considered.

The Technical Advisory Committee (TAC) to the Consultative Group on International Agricultural Research (CGIAR) organized an Expert Consultation on international buffalo research needs in 1976. The most important recommendation of this Consultation concerned the establishment of an international buffalo research project to assist in the development and strengthening of national research capabilities, coordination of research, exchange of information, training of research workers and the optimal use of existing research staff and consultants. The FAO/SIDA/Government of India Seminar on Reproduction and Artificial Insemination of Buffaloes held in India in 1978 also identified and discussed the fields in which research was required. This was followed in 1979 by the FAO/IAEA First Research Coordination Meeting on the Use of Nuclear Techniques to Improve Domestic Buffalo Production in Asia, held in Sri Lanka, which considered the need for research in those fields in which nuclear techniques could be of value. A

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COVER: Carabao (water buffalo) drawing the cart of a small farmer in the Philippines.

The ascendant water buffalo - key domestic animal

W. Ross Cockrill

*The water buffalo (*Bubalus bubalis*) is a neglected bovine animal with a notable potential for meat and milk production. World buffalo stocks, which at present total 150 million in some 40 countries, are increasing steadily. There are 19 distinct breeds.*

National stocks should be upgraded by selective breeding allied to improved management and nutrition but, from the standpoint of increased production and the full realization of potential, it is equally important that crossbreeding should be carried out extensively especially in association with schemes to increase and improve buffalo meat production.

Meat from buffaloes that are reared and fed for early slaughter is of excellent quality. Because the buffalo is a superb converter, meat can be produced at lower cost than that in the case of cattle and without the need for expensive fodders and concentrates.

There is growing interest in both the advanced and the developing countries in the full exploitation of the domestic water buffalo, as is shown by the expanding international trade in breeding stock and the establishment of herds in countries where the buffalo is a newcomer.

The water buffalo (*Bubalus bubalis*) is the world's most neglected domestic animal, and the one with the greatest unexploited potential.

A major reason for neglect is that the buffalo exists in greatest numbers in developing countries, mostly in the East, in which, until relatively recently, there have been few if any facilities for research and little incentive to improve existing conditions.

The animal commonly referred to in North America as the buffalo is not, properly speaking, a buffalo at all but a bison (see Figure 1), a distant cousin bearing roughly the same tribal relationship to the true Asian buffalo (see Figure 2) as does the sheep to the goat or the yak to the ox. The bison can be crossed with cattle to produce the cattalo, or beefalo, a heavy meat-type animal for which widely publicized claims have been made in recent years. The water buffalo has never been shown to produce offspring either fertile or sterile when mated with cattle,

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although under suitable conditions a bull will serve female buffaloes, while a male buffalo will mount cows.

There are about 150 million water buffaloes in the world compared with a cattle population of around 1 214 million. This is a sizeable figure, especially when it is considered that the majority of buffaloes are productive in terms of milk, work and meat, or any two of these outputs, whereas a high proportion of the world's cattle is economically of little value.

In the majority of buffalo-owning countries, and in all those in which buffaloes make an important contribution to the agricultural economy, numbers are increasing, sometimes at quite phenomenal rates. In some extensive areas buffaloes present a substantial challenge to cattle. In India, for example, which has the world's largest buffalo population (at least 60 million) the buffalo now supplies almost 70 percent of all the milk used for human consumption. The picture is similar in Pakistan where there are several outstanding milk breeds in a population of around 14 million. Buffalo stocks are steadily increasing while the number of cattle is decreasing. China, which has the second largest establishment with over 30 million, utilizes its buffaloes almost exclusively as work animals and, until very recently, has not taken advantage of its outstanding potential for milk and meat. There are indications now that China's dynamic progress in agriculture will be extended to the fuller exploitation of its domestic animals, among which the buffalo is one of the more important (FAO, 1976).

The growing awareness of the true value of the water buffalo is shown in Table 1 which lists buffalo popu-

TABLE 1. **National buffalo populations in selected countries, 1961-65 and 1979**

Thousands

Country	Average population 1961-65	Population 1979
Bangladesh	505	800
Brazil	67	210
Burma	1 117	1 900
Egypt	1 559	2 800
India	51 873	63 000
Iraq	238	340
Nepal	3 067	3 900
Pakistan	7 118	14 000
Philippines	3 357	5 050
USSR	385	520

Sources: 1961-65: **FAO Production Yearbook**; 1979: Author's estimate.

Figure 1. *The North American bison, commonly referred to as a buffalo, is a distant tribal cousin of the true domesticated buffalo of Asia*

(PHOTO: USDA, ISSUED BY FAO)

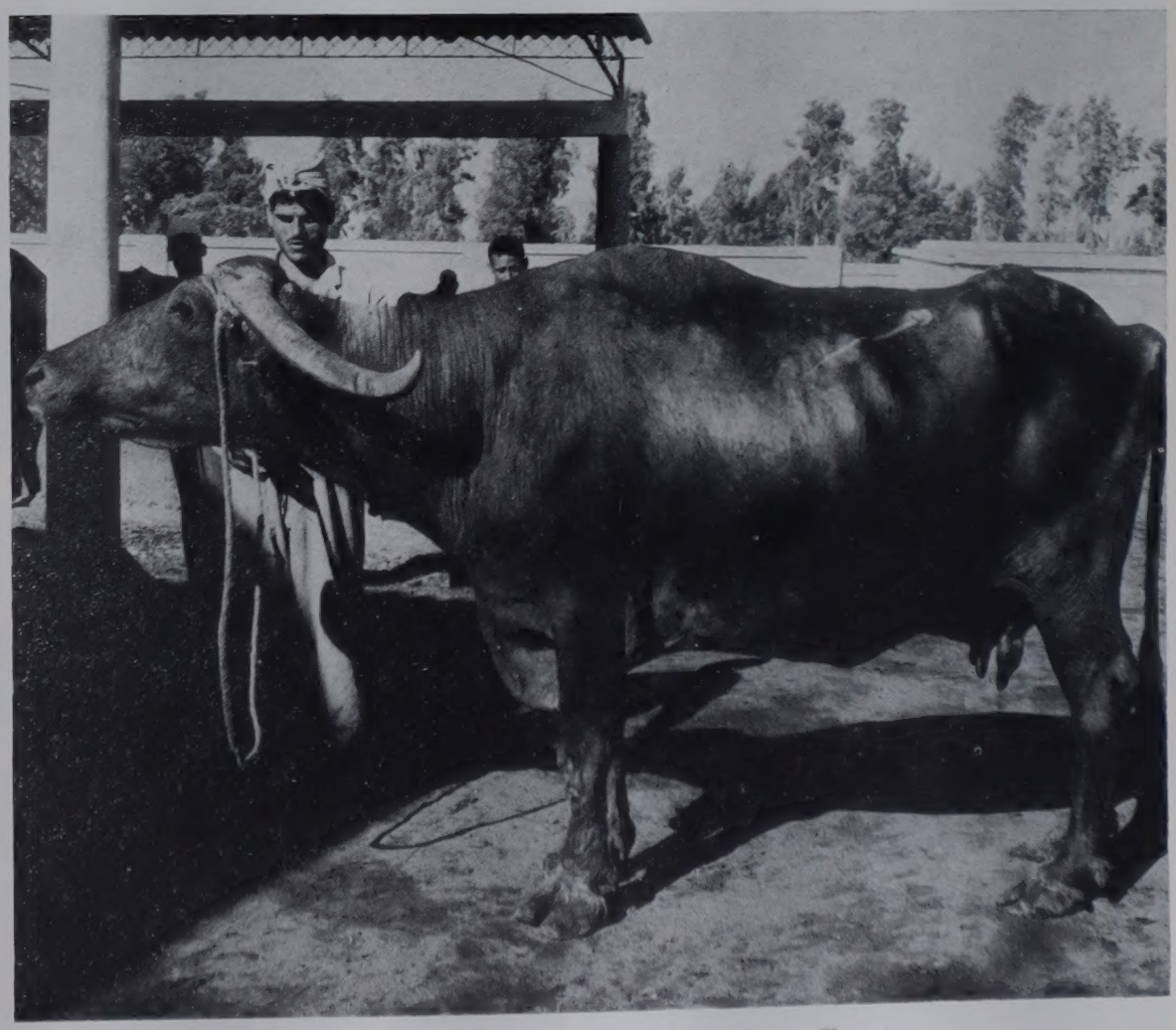
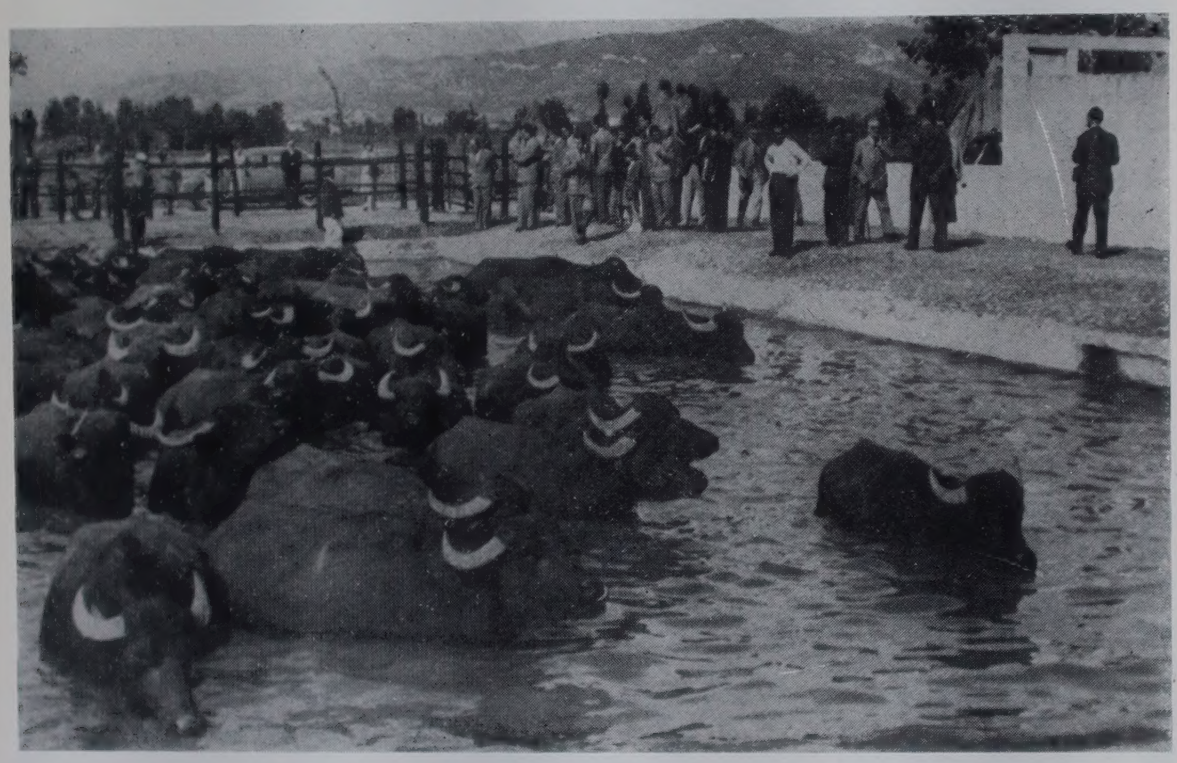
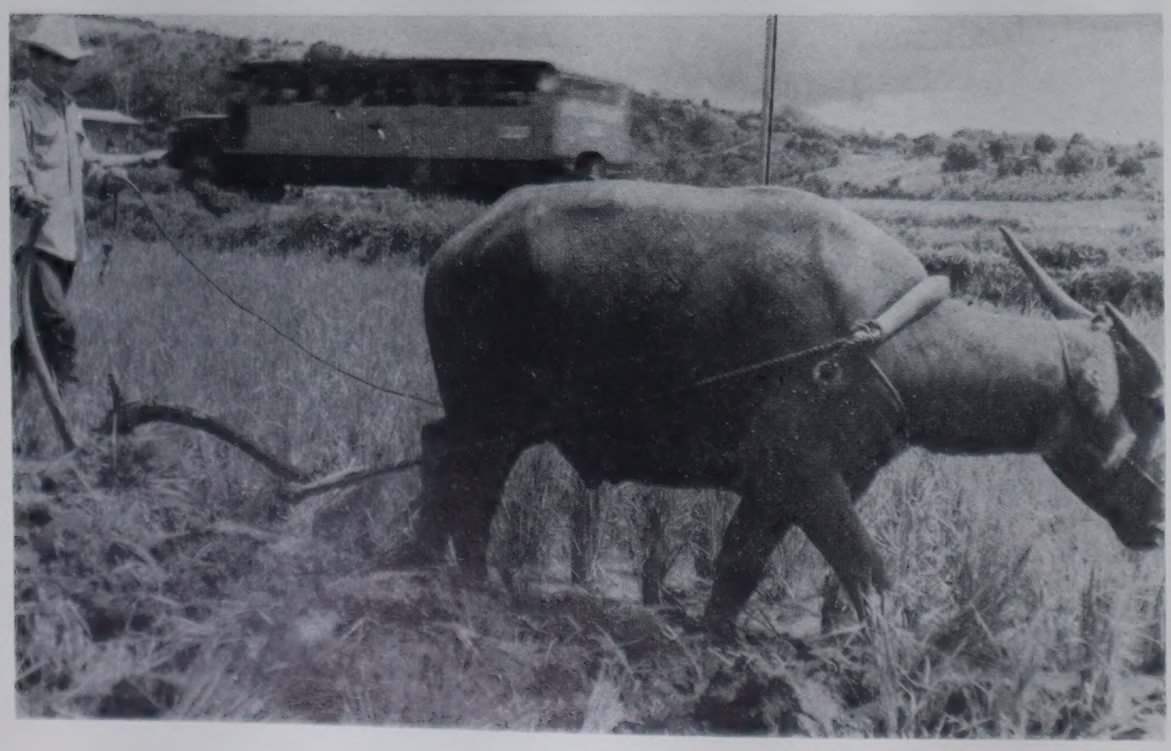


Figure 2. *Dairy buffalo cow in Upper Egypt*





lations in selected countries, in all of which the national buffalo population is increasing and is receiving official attention and support.

A number of countries in Latin America, including Colombia and Venezuela, have recently introduced nucleus breeding stocks from Australia, Trinidad and Tobago, and Italy. These are thriving well, as are new populations in Bolivia, Costa Rica, Nigeria, Mozambique and Papua New Guinea.

Buffaloes were introduced into Brazil at the turn of the century and there have been numerous importations since then. There are now five breeds in the country and a flourishing population approaching a quarter of a million. In the Amazon Valley the buffalo has adapted to its environment in a manner that can only be described as spectacular: the high fertility rate, early maturity, and outstanding meat production capacity would indicate that, within the next three decades, buffaloes will largely replace cattle. Given import facilities and sound management, the animal has a bright future almost everywhere in the Americas.

There have been buffaloes in a number of European countries for many centuries. These countries include Greece, Hungary, Romania and Yugoslavia. Perhaps the most salient are Bulgaria and Italy in both of which there are active research programmes and the native buffaloes, known as the Mediterranean breed, are thriving and multiplying. In Italy before World War II, Mussolini, regarding the buffalo as indicative of a primitive and backward agriculture, suppressed buffalo rearing and the population declined to a dangerously low level. With the fall of the Fascist regime the buffalo stocks began to increase and

Figure 3. *Buffaloes in Italy. Mozzarella cheese is made from their milk*

Figure 4. *A herd of Italian buffaloes being observed by FAO Conference delegates*

Figure 5. *Ploughing-in rice straw with carabao (water buffalo) in the Philippines*

Figure 6. *Threshing rice in Thailand*

Figure 7. *Turning a water wheel for irrigation in Egypt*

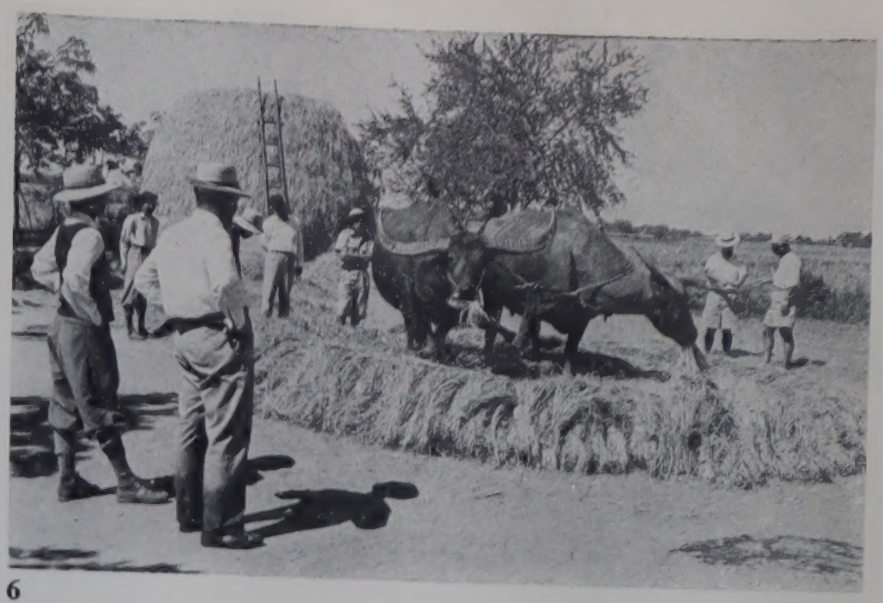
Figure 8. *Harvesting sugar cane in the Philippines*

Figure 9. *Buffalo sled of bamboo in Thailand*

Figure 10. *Buffaloes ploughing in West Azerbaijan, Iran*

Figure 11. *Raking rice land in Thailand*

Figure 12. *Ploughing with a wooden plough using an albino buffalo in Thailand*



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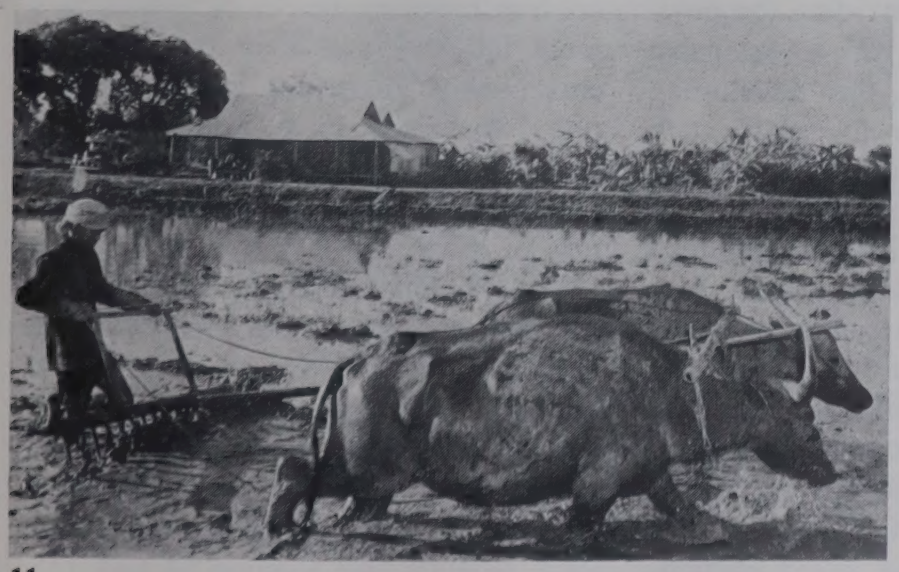

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Figure 13. *As a pack animal — Pakistan*

Figure 14. *Heavy loads drawn by buffaloes in Pakistan*

there are now well over 100 000 in Italy, utilized mainly for milk production with meat as an increasingly important sideline (see Figure 3). The history of the Italian buffalo dates back 1 000 years, during which time there have been no recorded imports. The Mediterranean buffalo is a blocky, high-yielding animal which combines both meat and milk characteristics. Some of the world's most advanced buffalo enterprises are located in the southern half of Italy and the breed is attracting a growing amount of attention from Latin American and African importers (see Figure 4).

In much of the developing world the buffalo is primarily a work animal. In the Indian subcontinent it is the supreme milk producer. Meat is a by-product of work and milk production but it is now emerging as perhaps the most important aspect of buffalo productivity for the future.

The working buffalo. From time immemorial the buffalo has been the working animal of the world's paddy lands, and an integral factor in the production of rice, which is the basic food of one half of the world's human population (see Figure 5). The original habitat was northern India and south China, and there is a history of domestication reaching back to at least 2500 B.C. They were first domesticated in the great riverine civilizations of the Euphrates and Tigris, the Indus and the Yangtze.

The domestic animals that have the greatest affinity for man are the horse, the dog and the water buffalo. This affinity and their docile temperament facilitated the taming and domestication of buffaloes — as is currently being demonstrated in Australia's Northern Territory. Buffaloes were introduced from Timor about a hundred and fifty years ago as a source of meat for the isolated military and administrative stations. Some escaped or were turned loose and a feral population quickly became established. These stocks are now being redomesticated. Two weeks after being rounded up in the bush and corralled for the first time they can be haltered and handled (Cockrill, 1974).

There are literally millions of domestic animals whose output is measured in terms of work rather than protein. They are mostly cattle, equines, camels and buffaloes, and they are used to plough, harrow and grade the land, to pull carts or drays, as pack animals and for general draught purposes such as raising water from deep wells or providing the power for mills. Their use is extensive throughout most of the developing world. The tendency to regard such use as indicative of a primitive agriculture needs to be corrected.

The work animal is generally economically efficient and is the best available means of carrying out work, especially for the many small farmers in the developing countries. The value of the buffalo has been considerably increased and emphasized in recent times by the rise in fuel costs, which has hit the developing world particularly hard and has caused some drastic rethinking in many areas where mechanization had begun to make advances in agriculture. Shortage of manpower is seldom a problem or a stimulus to mechanization in Third World countries where the man with his one or two work animals is the vital production unit (see Figures 6-12).

Only in countries where manpower availability is low and oil fuel is cheap, plentiful and readily obtained is there an economic argument for relegating the work animal to history. Although draught animals have virtually disappeared from the Western world, elsewhere their numbers are declining only slowly. They will long retain the place they have held in agriculture for the past four or five thousand years (Mason, 1974).

As mechanization advances, however slowly, it is important that the stocks of animals traditionally bred for work, as were the oxen of Europe, should not disappear. These are the nucleus breeding stocks of tomorrow's meat industry and they represent an enormously important genetic potential. Buffaloes have been bred for weight and muscle power, the qualities that must be exploited in the production of meat.

The swamp buffalo is the commonest working breed, but many of the milking breeds are also good work animals. In the East, the hardy, nondescript, mongrel *desi* buffaloes of no recognizable breed are commonly used on the roads as both draught and pack animals (see Figures 13 and 14).

Figure 15. *Wallowing buffalo in Iraq*

The milch buffalo. Roderick MacGregor, a veterinarian and pioneer buffalo worker, classified (MacGregor, 1941) the animals as falling into swamp and river groups, and it is convenient to consider all the breeds and types under these two headings (see Table 2).

The swamp buffalo is a breed in its own right. It has an outstanding potential for meat production and is capable, under suitable management, of producing a satisfactory yield of milk. It is widespread throughout southern China, Indonesia, Malaysia, the Philippines, Thailand and other countries of the Far East.

The river buffaloes include the milking breeds of India and Pakistan and some European countries. MacGregor, commenting on the wallowing proclivities of buffaloes, observed that the swamp types in general prefer a mudhole in which they like to acquire a generous plastering of mud, while the river types tend to favour ponds or slowly flowing water (see Figure 15).

All breeds present a picture of complete bliss when immersed in a wallow, whatever its nature. They chew the cud with half-closed eyes and utter typical deep sighs of contentment. The wallow and the mud plaster provide protection against the sun and biting insects.

While the buffalo is a remarkably versatile animal it is not adaptable in the physiological sense. It suffers discomfort if subjected to the direct rays of the sun for any length of time or if worked or driven excessively. If exposure is prolonged the distress becomes acute and prostration and death may follow quickly. Although by nature a semi-aquatic animal (see Figure 16), the wallow is not strictly necessary to its well-being. Buffaloes can thrive anywhere provided there is suitable pasture (see Figure 17), ample drinking water and sufficient shade to enable them to avoid the heat of the day. In temperate climates exposure to cold winds, draughts and rain also induces stress.

Most breeds are in the river category, are primarily milk animals, and originate in India and Pakistan.

Buffaloes may sometimes yield less milk than cows maintained under identical conditions. However, the average milking buffalo often gives much more milk than the average milking cow. In India, for example, the average annual milk production of the buffalo (491 kg) is 2.8 times higher than the annual average of the cow (173 kg). The number of buffaloes producing more than 2 kg per day is 188 per 1 000 compared with only 3 per 1 000 in cows (Shah, 1967).

In well-managed buffalo dairy farms, yields per lactation of 1 000 kg are common (see Figures 18-22). In the best enterprises in Italy, with twice-daily machine milking and a lactation

TABLE 2. **Breeds of buffaloes**

Main type	Breed	Production
Swamp	There are a great many local varieties, varying greatly in size, colour and markings. None of these can be accorded separate breed status. Horns are massive and grow outward from the head in a semi-circle.	Mainly used for work; exhibit great versatility and muscular power. The potential for meat production is outstanding. Small-scale milk production from the working animal is usual.
River	Horns curled and set close to head may be downswept: Jafarabadi Kundi Mehsana Murrah Nili-Ravi Sambalpur	Primarily milk producers, or dual purpose milk/meat animals. Most breeds have good beef characteristics.
	Horns sickle-shaped and upswept: Bhadawari Egyptian Jerangi Kalahandi Kanara Manda Mediterranean Nagpuri Pandharpuri Surti Tarai Toda	The production of beef-type calves by mating females with beef-type males, such as the Swamp, should be greatly extended. Crossbreeding offers great opportunities and should be encouraged.
Desi (mongrel)	Local types, nondescript and usually the result of haphazard, uncontrolled breeding. Horns may be of any shape but are most often curled.	Mainly working animals; ploughing, harrowing, road haulage and general draught purposes. Small milk production. Usually good beef potential.

period of 280 days, an average daily yield of 8 to 10 kg has become routine (see Figures 3 and 4). State and military farms in India and Pakistan record similar yields. In Bulgaria buffaloes often attain a yield of 2 000 to 2 500 kg per normal lactation period of 300 days while exceptional yields of 4 000 kg have been recorded. In India there are instances of Murrah buffaloes producing 5 000 kg in a single lactation.

The milk is very rich in both butterfat and in non-fat solids, but is otherwise closely similar in chemical composition, physical properties and acceptability to cows' milk. The average butterfat content is 7 to 8 percent. By feeding a high level of concentrates it can be made to exceed 15 percent.

A great variety of butters, including the dehydrated clarified form known as ghee — which is the cooking medium favoured by Muslims and Hindus — and cheeses are made from buffalo milk. Many of the cheeses, such as the Italian mozzarella and ricotta, the gemir of Iraq, the cincho of Venezuela, and the pecorino of Bulgaria are rare delicacies. Buffalo-milk yoghurt and curd are also worthy of mention.

It has been postulated that the water buffalo has little or no genetic potential for increased production of milk. This statement is often advanced during revivals of the sterile buffalo versus cow argument, but the evidence is insubstantial or sophistic. Kurien (1970), analysing the production performance of buffaloes and of indigenous and crossbred cows, noted that, in 1957, 0.18 percent of buffaloes in India had a daily milk production of over 12 kg. A less comprehensive survey made in 1937 indicated that 0.10 percent of buffaloes were producing 12.6 to 14.4 kg of milk daily. The next most productive 40 percent of buffaloes were producing some 4.5 kg daily in 1957. Use of the top 0.1 percent as nucleus stock, to be bred with the next most productive 30 percent of buffaloes, could be expected to produce a buffalo with a lactation yield and conversion efficiency equal to that of most crossbred cows in India. The potential for greater production of milk is at least as good as that of the cows. The same author points to the buffalo as an efficient converter of the coarse roughages that are a by-product of most farms and that are unsuitable for cows. In South Africa a small experimental introduction of buffaloes to a swamp area has shown that they can control dense growths of the grass *Paspalum vaginatum*. In swamp lands anywhere buffaloes can thrive on low-grade marsh vegetation (South African Digest, 1979).

Depending upon breed, environment and management, the daily milk yield of buffaloes ranges from the 2 to 4 litres produced by a working draught female to the 16 litres or more of the exceptionally heavy-yielding dairy animal. Buffaloes that combine milk production with work naturally give a lower milk yield than those maintained exclusively for milk.

The lactation period is usually 270 to 300 days. Yields vary with breed, location, nutrition and management from 500 to over 3 000 litres. The gestation period is approximately 310 days for most breeds. Two calves in three years is usual, though with good management a calf every 14 months is possible from the age of 3½ years to 18 or more. The buffalo is remarkable for its long productive life.

The dairy buffalo approximates closely to the dairy cow in many of its characteristics. Methods of breeding, husbandry, and feeding for milk production that have proved successful for the cow can be applied equally to the dairy buffalo (Kay, 1974). The buffalo has qualities of docility, longevity, and feed conversion possessed by no other domestic animal.

The beef buffalo. The classic procedure of mating dairy cows with beef bulls and raising the calves for early slaughter can be profitably applied to buffaloes. The production of buffalo meat from dairy herds by the use of beef-type males of the swamp breed, for example, on such milking breeds as the Kundi, the Surti and the Mediterranean, offers opportunity for development. The application of artificial insemination, and the storage and use of deep-frozen semen presented many difficulties in buffaloes but research in Bulgaria, India and Pakistan has now brought the techniques to the level and efficiency they have attained in cattle. Artificial insemination in progeny testing is now a highly important tool in improving buffalo breeds and crossbreds.

The value and importance of the working buffalo and the milking buffalo have obscured the outstanding potential of the animal for meat production. While much can be done to increase work output and to improve milk yield and quality, it is possibly in the realm of meat production in both developing and developed countries that the buffalo can make its greatest contribution (see Figures 23 and 24).

The water buffalo is the ideal animal for feedlots. It is a highly efficient converter, it is not liable to many of the stresses that afflict cattle, it is placid and non-aggressive by nature, and it can be herded and handled with ease. The feedlot practices normally used with cattle would require only minor and inexpensive adaptation. All buffalo calves should be dishorned at or before the age of six months. Males should be castrated at the same time. Shade must be provided but wallows are not necessary, though routine spraying would be beneficial.

The buffalo is a bovine animal and there is nothing peculiar about its flesh. It does not have a "buffalo flavour". It is not second best to cattle beef. It can stand on its own merits and deserves recognition by a meat-hungry but discriminating public as a meat fit to rank with the best of beef. There are no significant differences. The two meats are closely similar in chemical and physical properties. Buffalo meat differs from cattle meat only in having less fat and being more tender.

Results obtained in Bulgaria and Yugoslavia showed daily weight gains of over 1 kg. De Franciscis (1971) in Italy, and Mesbah *et al.* (1973) in Egypt have convincingly demonstrated

Figure 16. *Buffaloes at Hor Haveza, Taraba in the marsh areas of southern Iraq*

Figure 17. *Tethered buffalo grazing in scrub in Thailand*

that the early weaning of buffalo calves and subsequent rearing for beef production, with slaughter at around one year of age at a liveweight of 300-320 kg, is perfectly feasible. A highly satisfactory yield of top-quality beef is obtained at a much lower cost with buffaloes than with cattle. Dressed carcass percentages range between 50 and 58 and the meat component is around 70 percent of the meat-bone total.

Much useful work on buffalo meat production has been done in Australia in recent years. It is only since 1968 that the potential of the feral buffaloes has come to be appreciated. Until then the buffaloes of the Northern Territory had been regarded as a pest, to be cropped for the hides as expedient, and eliminated if possible. The work of Tulloch (1970, 1974), who first studied the behaviour of the feral buffaloes and who demonstrated the ease with which they can be tamed and domesticated, has opened the way to a new industry in the "Top End" of Australia's Northern Territory.

Charles and Johnson (1972, 1975) have demonstrated that buffalo carcasses are well suited to the lean-meat market and have a higher dressing-out percentage than those of the *Bos* species. They have shown that castration makes little difference to the carcass characteristics of the swamp buffalo, and that even on high-gain rations the carcasses will be lean. Average weight gains in four feedlot groups, each of five 200- to 300-kg, 11- to 20-month-old steers, fed lucerne hay or pellet rations for 3 to 5 months, were 0.5 to 0.74 kg/day. Fattening periods were 3 to 5 months and slaughter was at liveweights of 300 to 480 kg. It is suggested that buffalo steers will only become overfat after prolonged feeding to weights well above commercial targets. Excess fat, i.e., over 20 percent, was produced only after a long stay in the feedlot and in the oldest of the steers. A comparative study that confirmed the resistance of the buffalo to fattening was made with Hereford, Friesian, Angus and swamp buffalo steers that were fed concentrate rations for between 3 and 7 months. All breeds except the Angus put on the same amount of muscle but differing amounts of fat. The buffaloes finished with much leaner carcasses.

For many centuries buffaloes were bred and kept for work. This led to the evolution of animals of powerful muscular development. Until relatively recent times little attention was given to the exploitation of this potential for quality meat supplies. Most of the buffalo meat was, and still is, derived from animals slaughtered in emergency or at the end of a useful working or milking life. As a result, the meat is generally of poor quality and is often unattractive in appearance. Rearing buffaloes for meat production is still in the early stages but already shows promise of rapid expansion in many countries. The wide variation in size and weight of buffaloes in different countries, ranging from 250 to 1 000 kg or more, indicates a considerable potential for selection for breeding. However, it is vital to ensure that improvements in management, nutrition and health protection keep pace with breed development. Research programmes on many aspects of meat production are under way at centres in Australia, Bulgaria, Egypt, India, Italy, Romania, Trinidad and Tobago, the USSR and Yugoslavia (FAO, 1977).

The buffalo is an animal not of the past but of the future. An important part of that future lies in its potential as a source of quality meat. If the buffalo is reared and fed for meat production the meat is tender, palatable, of high quality and acceptable to the consumer. It can be obtained at less expense and with fewer inputs than that from cattle and, in tropical and subtropical countries particularly, at a much earlier age.

Health. It is unfortunate that some of the best buffaloes, especially those of the river breeds, are in areas where the incidence of certain infectious or contagious diseases is high. This causes many countries, and in particular those in the West, to refuse the importation of these animals. Some developing countries, following the example of the majority of the advanced countries, will not accept the risk of importing from these sources even when such risks can be reduced to negligible proportions. Systems of close and prolonged quarantine, under maximum security conditions, allowing for the application of detailed tests with constant veterinary supervision at both export and import points, minimize the danger and render possible the introduction of nucleus breeding herds of appropriate breeds even into countries where buffaloes have not previously existed. It is considered worthwile to accept such greatly reduced risk in order to add a highly productive source of protein to animal agriculture.

The water buffalo must be seen as an animal with an outstanding production future, not only in tropical and subtropical countries but in many of those in temperate zones also. The dairying and meat production industries, which have had an important supporting role in the evolution of social systems, are now taking a leading position in raising standards of living.

As a bovine animal buffaloes are as susceptible to the majority of infectious conditions as are cattle. Opinions are sometimes expressed that water buffaloes are resistant or even immune to many of the infections of cattle and other species. It is true that some diseases are less prevalent in buffaloes than in cattle or are less harmful; others, however, are more prevalent and more harmful, while a limited number of disease conditions and parasitisms of minor economic

Figure 18. *Buffalo dairy herd under modern conditions on a military dairy farm in Pakistan*

Figure 19. *Nili-Ravi milking buffaloes at Qadirabad Government Livestock Farm in Pakistan*

Figure 20. *Dairy buffalo cow on Government Station in Pakistan*

Figure 21. *Town milk-production and direct retail milk-selling in Pakistan*

Figure 22. *Buffalo belonging to a cooperative member of the Anand Milk Union, India*

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importance appear to be specific to buffaloes. Reaction to some diseases seems to vary with geographical location, environment and breed, but it can be accepted that unvaccinated buffaloes have little or no resistance to the major epizootics such as rinderpest and food-and-mouth disease. The myth of their immunity to tuberculosis and the infectious infertilities has long since been exploded. In the author's experience mastitis is not of such frequent occurrence in buffaloes as it is in cattle and is seldom seen in the acute form. Similarly, pathogenic processes of the feet, such as foot rot and foot abscess, are extremely rare in buffaloes. There is a strong, but unfortunately not absolute resistance to tick infestation. This is often and erroneously attributed to the thickness of the hide. The hide is certainly thicker and heavier than in most breeds of cattle and is very vascular. There is no immunity to piroplasmosis, trypanosomiasis, and East Coast fever. Buffaloes, by virtue of their habitat and wallowing proclivity, are subject to heavy infection with *Fasciola* spp. which may cause loss in production and reduced work ability. Although the liver may suffer extensive and irreparable damage and the parasite load may be phenomenally heavy, clinical signs are usually lacking. *Neoscaris vitulorum* infection, which may be acquired prenatally, or through the colostrum, causes heavy losses in untreated buffalo calves in which the small intestine may be packed to the point of complete occlusion.

Although the buffalo presents some characteristic features, and some of these may appear to be unique, it is a bovine animal and its response to infection is very similar to that of cattle. When maintained under good conditions of health control, it is remarkable for its long productive life. There is some truth in the aphorism that a sick buffalo is a dead buffalo.

The future of the water buffalo. Table 3 shows the importations of nucleus buffalo breeding stocks in recent years.

Some of these importations, e.g., by Costa Rica, have been small and experimental; others, like those by Mozambique, Nigeria, the USSR and Venezuela, have consisted of imports of some hundreds of animals repeated on several occasions and designed to boost existing populations where there is an obvious commitment to the future of the buffalo.

TABLE 3. **Importations of nucleus buffalo breeding stocks**

Importer	Supplier
Bolivia	Brazil
Brazil	India, Italy, Trinidad and Tobago
Bulgaria	India, Pakistan
China	India, Pakistan
Colombia	Trinidad and Tobago
Costa Rica	Australia
Mozambique	Italy
Nigeria	Australia
Papua New Guinea	Australia
Tanzania	Egypt
Uganda	India
USSR	India
Venezuela	Trinidad and Tobago, Italy, Bulgaria and Australia

In Italy and elsewhere the water buffalo has amply demonstrated its claim to an important place in Western agriculture. In the developing countries the numbers of buffaloes maintained for milk and meat production are greatly increasing. Scientific interest in stimulating production through intensive studies and research is growing everywhere.

The future for this attractive, tractable, productive animal appears to be a bright one in which the promise of an outstanding contribution of animal protein in the form of high-grade milk and top-quality meat should be fulfilled. ■

Figure 23. *Buffalo steers, aged 20 months, after 3 months of grain feeding, averaging 450 kg weight, in Thailand*
(PHOTO: J.E. ROUSE)

Figure 24. *Buffalo market in Pakistan*

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A review of the prospects for vaccination in African trypanosomiasis

Part II

M. Murray, J.D. Berry, W.I. Morrison, R.O. Williams, H. Hirumi and L. Rovis

In Part I of this review of the prospects of vaccination against African trypanosomiasis, contained in the previous issue of World Animal Review, the constraints in developing a vaccine were discussed and current knowledge on the molecular biology of the trypanosome and on antigenic variation with respect to possible future vaccines was evaluated. In this part other possible regimes for immunological intervention, including the immunogenicity and cross reactivity of trypanosome subcellular fractions, reduction of host susceptibility to African trypanosomes by the non-specific use of immunostimulants or chemotherapy and also the role of trypanotolerant livestock in such approaches, are discussed.

Immunogenicity of subcellular fractions. Modern biochemical technology has allowed the isolation, purification and characterization of a whole range of trypanosomal subcellular fractions. Thus, the variable antigen, which is responsible for induction of protective immunity, has been shown to be a glycoprotein with a molecular weight of 60 000 to 65 000 daltons, depending on species (Cross, 1975 and 1977 with *T. brucei*; Baltz, Baltz and Pautrizel, 1976, and Baltz *et al.*, 1977 with *T. equiperdum*; Rovis, Barbet and Williams, 1978 with *T. congolense*). While (at least with *T. brucei*) the N minerals of different variable antigen types (VATS) differ in amino acid sequence (Bridgen, Cross and Bridgen, 1976), there is now evidence that different VATS of the same and also of different species of trypanosomes (*T. brucei*/*T. congolense*) may have cross-reacting determinants (Barbet and McGuire, 1978). Although it would seem likely that these are hidden from the host's immune response the possibility of vaccination against these determinants must be pursued.

Cross-reaction may occur at different levels. For instance, some cross-reacting determinants may be found only on VATS within one VAT repertoire (the total number of VATS that a trypanosome can express), while others may be universal. Complete characterization of all determinants, using such techniques as monoclonal antibody production (Köhler and Milstein, 1975), should reveal the structural and functional significance of any cross-reacting components. Hyperimmunization against such components may prove effective if manipulated properly.

Most biochemical and immunological studies to date relating to immunogenicity of subcellular fractions have been aimed at analysing the variable antigen of the surface coat. It is possible, however, that at some time in the trypanosome's complex life-cycle "weak spots" amenable to im-

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munological control might be exposed. Thus, recent investigations have been made into the purification of a range of subcellular fractions of the trypanosome such as flagellum, membranes and kinetoplast. The biological characteristics and immunogenicity of these fractions have been investigated and compared with those of variable antigen. What the authors have found in studies on *T. brucei* in the mouse is that flagellum and membrane fractions stimulate protection against homologous VAT challenge to the same degree as variable antigen (Table 1). It is likely that this is the result of the presence of variable antigen in these subcellular fractions although it is interesting that, per unit weight protein, flagellum is more effective than the purified variable antigen. No protection was achieved on challenge with a different VAT although with the membrane and kinetoplast preparations there was significant prolongation of survival accompanied by an alteration in the parasitaemic profile. This was possibly a result of a non-specific stimulant effect of these fractions (see below, the section on "Induction of increased resistance by immunostimulants").

Using a subcellular fraction of *T. brucei* or *T. rhodesiense* that probably contained a mixture of variable antigen, mitochondrion and kinetoplast to immunize mice, Powell (1976; 1978) found increased survival times and reduced parasitaemias in mice challenged with *T. brucei*. Using *T. brucei* in *C57Bl/6J* mice and a similar fraction for immunization, the authors were able to stimulate protection only if trypanosomes of the same VAT were used for challenge (Table 1). When another VAT was used for challenge protection was not achieved although there was a significant increase in survival time. Of considerable interest is the report of Powell (personal communication) that the use of the above fraction in aluminium hydroxide protected across trypanosome species. Three sheep were immunized in the "feet" with three doses of 1-mg protein fraction of *T. rhodesiense* in aluminium hydroxide. On subsequent challenge with *T. vivax* each of the three sheep developed a transient parasitaemia and then made a complete recovery. All three challenge control sheep became infected and died. These observations now await confirmation.

TABLE 1. **Immunization with various subcellular fractions of Trypanosoma brucei**

Fraction	Challenge	
	Same VAT	Different VAT
Variable antigen	Complete protection	No effect
Flagella	Complete protection	No effect
Membrane	Complete protection	Prolonged survival
"Powell" fraction	Complete protection	Prolonged survival
Kinetoplast	Increased resistance	Prolonged survival

Immunological intervention against the tsetse fly. It should be borne in mind that trypanosomes have a complex life-cycle in which there may be "weak spots" susceptible to immunological intervention. For example, stimulation of the mammalian host's response to the tsetse bite or saliva may be such a method. Also, the trypanosomes in the midgut of the tsetse fly are uncoated (Vickerman, 1969) and possess a common surface antigenic identity (Seed, 1964; Barry and Vickerman, 1979). As ingested antibody can retain specific activity for up to four days in the tsetse midgut (Cunningham *et al.*, 1962) it would be of interest to study the effect on fly infection of uptake of high levels of antibody against these common surface antigens (Barry and Vickerman, 1979). Once again, the antigen could be supplied by *in vitro* culture techniques.

Induction of increased resistance by immunostimulants. The host's immune response to the trypanosome is still poorly understood but there are indications that it is defective. For example, a feature of African trypanosomiasis is the development of a state of immunosuppression (reviewed by Murray *et al.*, 1974) and hypergamma-

TABLE 2. **Effect of Bordetella pertussis on survival of A/J and C57Bl/6J mice challenged with Trypanosoma congolense**

Percentage survival

Days after challenge	A/J [1]		C57Bl/6J [1]	
	Control	B. pertussis	Control	B. pertussis
10	68	96	100	100
15	0	43	88	100
20		43	88	96
30		43	88	96
40		39	80	96
50		35	80	91
100		8	26	64
150		0	0	24
Average time to death, in days	11.2 ± 1	26.4 ± 24.6 [2]	74.5 ± 35.4	113.3 ± 47.8 [2]

[1] 25 mice per group. — [2] Significant to controls (arithmetic mean ± one standard deviation).

globulinaemia — involving mainly *IgM* (Mattern *et al.*, 1961; Luckins, 1972), a large proportion of which would appear not to be specific for the trypanosome (Freeman *et al.*, 1970; Corsini *et al.*, 1977). It is possible that the capacity of the trypanosome to survive may be related to the immunologically compromised state of the host. Thus, a complete understanding of the basis of immunosuppression and the relevant immunological effector mechanisms that kill the trypanosomes might allow some form of intervention so that effector mechanisms are stimulated and the host is able to control or eliminate the parasite.

In this regard, the authors attempted to improve the host's immune response, and thus host resistance, by using the immunostimulants *Bordetella pertussis, Corynebacterium parvum* and Bacillus Calmette-Guérin (BCG) prior to or at the time of challenge (Murray and Morrison, 1979). So far this strategy has been successful, at least in mice. It was possible to increase survival times in both susceptible (*A/J*) and more resistant (*C57Bl/6J*) strains of mice (Table 2). Thus, following challenge with *T. congolense*, the treated *A/J* strain behaved in a manner much more akin to the more resistant *C57Bl/6J*. It should be emphasized, however, that complete protection was never induced by this method. The reduced susceptibility appeared to be related to the ability of these immunostimulants, particularly *B. pertussis* and *C. parvum*, to delay the onset of parasitaemia or to reduce the level of parasitaemia (Figures 1 and 2). The best results were achieved when both of these parameters were affected. The possibility that these immunostimulants acted by improving the immune response is being investigated at present.

The strategy of increasing host resistance by non-specifically acting immunostimulants offers an attractive alternative or additional approach to the complex undertaking of a breeding programme for trypanotolerant livestock. However, whether immunostimulants can be employed effectively in this way in domestic livestock remains to be determined

Trypanotolerance. As trypanotolerance was the subject of an earlier review in this journal (Murray *et al.*, 1979), the authors will limit their remarks.

There is now a substantial body of evidence to indicate that certain breeds of cattle, sheep and goats are able to survive and be productive without the aid of treatment in areas of tsetse-fly challenge, where other breeds cannot. This attribute is known as trypanotolerance although, as this state is not absolute, it would be better termed as reduced susceptibility. These trypanotolerant breeds are of considerable interest and importance. Not only is there evidence that they are economically exploitable in their own right but they also provide an excellent experimental system for evaluating the important factors that influence host susceptibility to trypanosomiasis. If it is confirmed, as the results of Desowitz (1959) strongly indicate, that the basis of trypanotolerance is the ability to mount a more effective immune response to the trypanosome, it might well be that any immunotherapeutic strategy that may be developed would be more effectively employed if used in trypanotolerant breeds of animals.

Infection and treatment. Bevan (1928; 1936), working in Southern Rhodesia, was perhaps the first worker to note that bovines that recovered from clinical trypanosomiasis after treatment frequently remained in good health despite reinfection, suggesting that it might be possible to create a "non-sterile" form of immunity. That infection and treatment regimes can achieve this has been confirmed more recently by Wilson and his colleagues working in East Africa (1957 a and b; 1976). Since the method developed is immediately applicable, the authors would like to describe these studies in some detail.

Wilson attempted to evaluate the use of different drug strategies in the development of immunity in young cattle over a period of two to three years. "Immunity" was assessed by trypanocidal drug requirement, development and duration of parasitaemia, ability to maintain normal blood values in the presence of parasites, calving rates in breeding stock and growth rates in a beef herd.

In one experiment a breeding herd located in a high tsetse-fly challenge area was managed under the following drug regime. Animals were treated with Berenil, treatment being determined not by the presence of the parasite but on the basis of the development of clinical signs of disease and of packed red cell volume (PCV) below 20 percent (Wilson, Paris and Dar, 1975a).

During the first and second years requirement for treatment did not change; an average of eight treatments was used and animals became parasitaemic about 30 to 40 days after each treatment. However, during the second year there was indirect evidence of reduced susceptibility to trypanosomiasis: for example, the number of live calves born increased and subsequent mortality decreased; abortions, a not uncommon occurrence in bovine trypanosomiasis, also decreased.

Even more promising results were achieved in a later series of experiments in which steers were introduced into an area of medium trypanosome challenge (Wilson *et al.*, 1975b; Wilson *et al.*, 1976). As before, a treatment regime based on appearance of clinical signs or PVC below 20 percent was used in a first group of cattle over a period of 29 months. The period between drug treatments, which was initially between 50 and 60 days, increased to around 130 days by the ninth treatment; at the same time the periods when trypanosomes were present in the blood without great adverse effect had increased from a mean of 11.7 days prior to the first drug treatment to 30.9 days by the ninth treatment. When the drugs were withdrawn from a number of steers six months before the end of the experiment, all survived and the growth rate and PVC values were the same as in the steers with access to therapy, showing that the resistance that developed was not drug dependent.

In contrast, a second group of steers, all of which were treated with Berenil whenever blood infection rather than clinical signs was detected, showed no

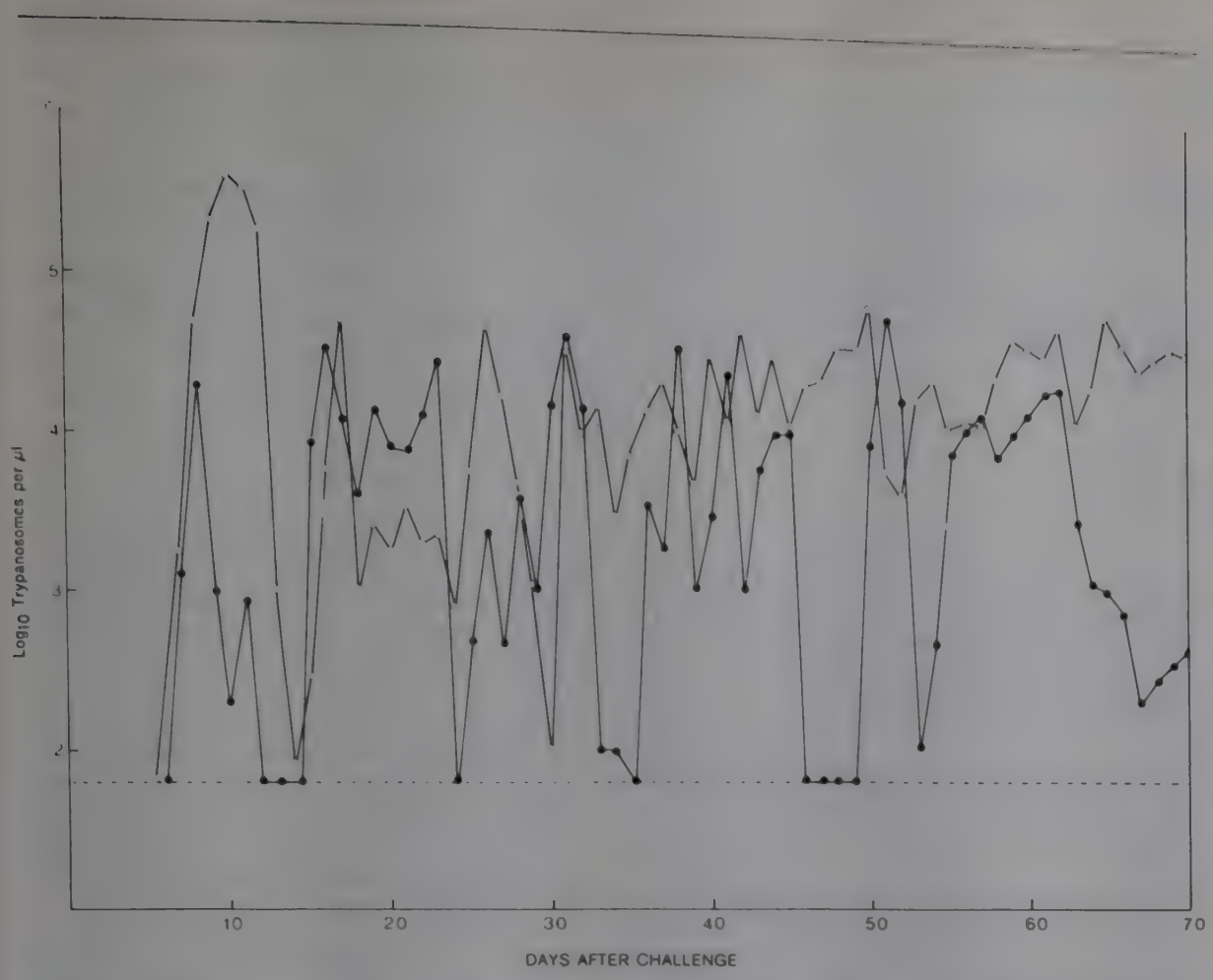

Figure 1. *The parasitaemia profile of a* Bordetella pertussis*-treated C57Bl/6J mouse (•) and a control C57Bl/6J mouse (o) challenged with* Trypanosoma congolense. *The broken line just below 2 $\log_{10}$ trypanosomes per µl indicates the level of sensitivity for detection of trypanosomes with the haemocytometer technique.*

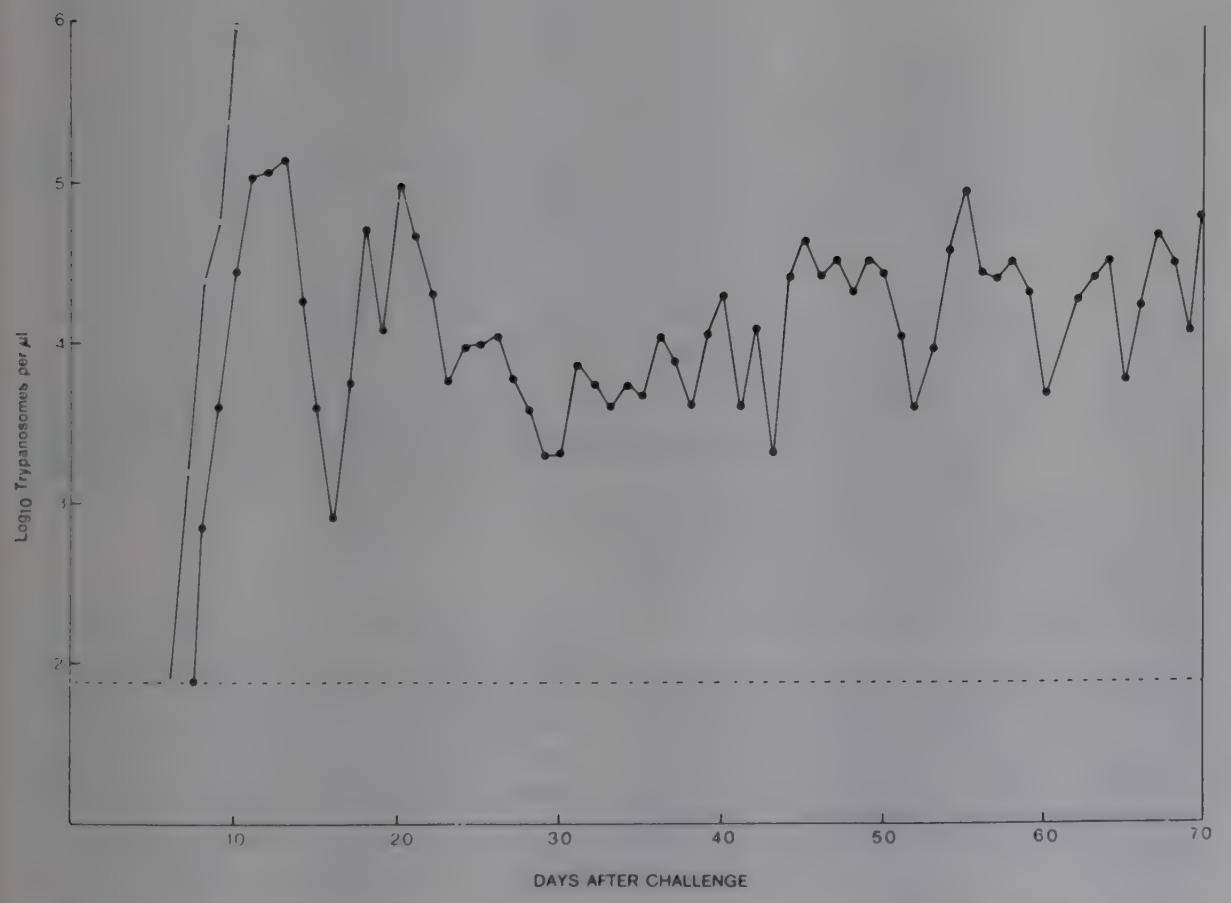

Figure 2. *The parasitaemia profile of a* Bordetella pertussis-treated *A/J mouse (•) and a control A/J mouse (o) challenged with* Trypanosoma congolense. *The broken line just below 2 $\log_{10}$ trypanosomes per µl indicates the level of sensitivity for detection of trypanosomes with the haemocytometer technique.*

evidence of developing immunity and they required treatment every 26 days throughout the course of the experiment. When treatment was withdrawn from some of the steers six months before termination of the experiment, their mean weight gains were 58 kg less than those steers in which treatment continued and, in addition, one animal died.

With a third group of steers, Samorin (isometamidium) was used in the same way as Berenil in Group 2, and there was some evidence of the development of immunity. While the need for therapy did not decrease throughout the experiment, PVC values and growth rates were maintained in the animals in which drug treatment was withdrawn six months prior to termination of the experiment, despite the more frequent presence of parasites in this group.

In terms of weight gain there was no doubt that the use of drugs prophylactically on a group basis, particularly Samorin, gave by far the best results. Nevertheless, as Wilson *et al.* (1976) pointed out, the particular advantage in encouraging the development of non-sterile immunity by infection and treatment might lie in the development of less-susceptible breeding herds over periods of several years, particularly in areas of low to medium trypanosome challenge. This procedure might be even more successful if used with trypanotolerant breeds of livestock. It should be emphasized that drug resistance was not experienced in these studies.

The basis of this form of tolerance or "non-sterile" immunity to the trypanosome awaits investigation. It may be that the host has built up a whole battery of immune responses to the range of metacyclic antigens and VAT repertoires that occur in that particular location, or alternatively there might exist a common priming antigen that allows the host to make a series of secondary responses to each VAT, thus controlling the infection in the manner of the carrier-hapten effect proposed for malaria by Brown (1971). However, it might be related to some non-specific effect such as expansion and activation of the mononuclear phagocytic system.

Conclusions. While a vaccine against trypanosomiasis is not an immediate prospect, what the two parts of this article have attempted to show is that there are several promising avenues for immunological exploration, namely VAT cocktails, trypanosomes attenuated in *in vitro* culture systems, genetic engineering, cross-reacting subcellular fractions, intervention against the tsetse, non-specific induction of increased resistance by immunostimulants, and infection and treatment regimes. It is likely, if any one of these areas is rewarding, that the resulting vaccine will be more successfully exploited, at least initially, in trypanotolerant animals.

The authors would like to emphasize that any immunotherapeutic solution for trypanosomiasis control can come only through a thorough knowledge of the life-cycle of the trypanosome and its basic biology coupled with a comprehensive understanding of the immune response of the finite host. ■

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The control of echinococcosis in Cyprus

K. Polydorou

The term echinococcosis, or hydatid disease, signifies infection of sheep and certain other animals, as well as man, with the larval stage of the tapeworm Echinococcus granulosus, *which, in its adult stage, is found in the small intestine of the dog and some other carnivores. The larval stage of the tapeworm is known as an hydatid cyst or* Echinococcus.

Sheep, through their close contact with sheepdogs, pick up eggs from tapeworm segments excreted by the dog onto pastures. These eggs develop into hydatid cysts in the sheep's liver, lungs and other organs. In a similar way, man, especially in childhood, may become infected by hydatid cysts through close contact with dogs. Such infections have very serious consequences and require surgical treatment.

Hydatid disease is, therefore, a serious threat to human health. It can only be controlled by preventing dogs from feeding on infected raw offals from sheep. If eaten by dogs, each cyst taken in develops into a large number of tapeworms in their small intestines.

Cyprus is one of the few countries that has been able to control and eradicate the disease.

Cyprus is the third largest island in the Mediterranean with a population of about 660 000 people. It has an area of about 9 252 km² and is predominantly an agricultural country. In 1977 the value of livestock production was about C£25 million — about one third of the country's gross agricultural income. Sheep and goat production is largely semi-transhumant but intensive units have been established recently as a result of the importation of superior quality breeds such as the Chios and Awassi sheep and the Damascus (Shami) goat. The dairy industry has also expanded as a result of the introduction of black-and-white Friesians. The island is self-sufficient in pork and poultry products. In 1977 there were about 265 000 sheep, 205 000 goats and 15 000 dairy cows.

In the past animal and poultry husbandry were adversely affected for many years by a number of serious diseases such as anthrax, sheep pox, bluetongue, foot-and-mouth disease, and hog cholera. All these diseases have been successfully eradicated. Parasitic diseases are still, to some extent, a problem although control programmes are being implemented.

Echinococcosis was one of the worst parasitic diseases, causing considerable losses to the livestock industry. It was also a grave public health problem. The purpose of this article is to describe the problems arising from the presence of the parasite on the island, the measures taken for its control and the results of a special campaign undertaken to eradicate the disease from the island. *Echinococcus granulosus* was identified by Batsch in 1786 as the cestode present in Cyprus.

The problem

During the early years of this century animal movements from and to the island were frequent and largely uncontrolled. Countries from which animals were brought to Cyprus included Turkey, Israel and other close neighbours. These movements included not only food animals but also dogs. How, when and from where echinococcosis came to Cyprus is a matter for speculation. Once the disease had entered Cyprus, however, its spread was greatly facilitated by the close contact that Cypriots have with their animals and also by the prevailing conditions on the island.

Most of the people were farmers and each family kept its own small flock of sheep and goats together with a few draught animals (indigenous cattle and mules, etc.) for working their fields and for transport. The sheep were kept in the yard of the house and the large animals often in the family's sleeping rooms so as to provide heat during the cold, wet winter nights. This was also a way of keeping a close watch on the animals, since theft was common. Because of this latter factor, large numbers of dogs were kept in order to guard the owner's property, including his animals.

Slaughter of animals was carried out in the home yards where the animals were kept, the viscera being given to the dogs. When animals were slaughtered in the village square the dogs present were also given unwanted pieces of offal.

In the countryside carcasses of sheep and goats that had died from disease were generally left unburied and these provided a natural source of food for a thriving population of stray dogs.

In the towns the feeding of dogs was more of a problem. Usually table left-overs, if anything, were given. In some instances the cheaper forms of offal, including "white-liver" or lung were fed. In towns dogs could be seen everywhere, but particularly in the vicinity of abattoirs and at refuse disposal areas. Often they roamed the fields around the towns in search of

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animal carcasses. Thus, infection among these dogs was common and this was a definite hazard to the townspeople who, in the main, were unaware of the danger.

The people of Cyprus, generally, are kindly disposed toward their dogs and dislike having to kill them. When their bitches had puppies, therefore, rather than killing them they would go to considerable trouble to abandon them under conditions where they could survive, thus further compounding the stray dog problem.

The presence in the country of packs of ownerless dogs, associated with a high level of hydatid disease, was first mentioned in 1929. These packs of dogs, when hungry, could be dangerous to children. There is no record of any child being killed in this way, but there are known to have been some lucky escapes.

The municipalities took what action they could including the use of dog catchers and nets. At various times attempts were made to involve the police and the staff of the Forestry Department in controlling the number of dogs in rural areas by shooting; but the work was unpopular and outside their normal duties, and the natural level of the stray dog population was soon restored.

From time to time committees were formed, propaganda campaigns were launched and anthelmintics were issued free of charge to dog owners. Generally, the impact of all these measures was negligible. The public were apathetic; they loved their dogs, were sympathetic toward the strays and just did not want to know about hydatid disease. Among official bodies none felt it was their specific responsibility to deal with the problem, and the half-hearted and ineffectual attempts which were made did little to alter the situation.

At last in 1970, the whole problem was properly tackled for the first time. A 15-year plan for eradication was drawn up by the present writer and approved by the Government.

The campaign plan

All the necessary actions for controlling and eradicating the disease were outlined in the form of a time-table under which it was envisaged that in 15 years echinococcosis would be completely eradicated from the island. The main feature of the plan was that the campaign was to be undertaken entirely by the Veterinary Department, which would be responsible for all the measures to be taken, i.e., extermination of stray dogs, control of slaughter, education of the public, assessment of the progress of the campaign and any other action that was deemed necessary for the success of the campaign. The Government arranged for the Veterinary Department to obtain the cooperation of other government departments in the campaign whenever this was necessary.

A meat inspection officer indicating hydatid cysts on a liver

Slaughter control — A fenced abattoir with a furnace

The campaign, initiated in 1971, included the following detailed provisions:

- The control of dogs on the island. In order to achieve this, every effort was made first of all to eliminate all stray dogs and enforce complete control over the remainder so that dogs would no longer perpetuate the life-cycle of the parasite. The spaying of bitches, for example, was encouraged, this being done as a free service at all veterinary stations.
- Public information and education, so that the campaign staff could obtain the full cooperation of the people of the island, who would then feel they were a part of the campaign against echinococcosis.
- The control and supervision of the slaughtering of animals as the intermediate hosts of the parasite. For this purpose suitable slaughterhouses were constructed in the town as well as in the rural areas. Campaign teams examined all carcasses to ensure that the infected viscera were disposed of safely.

Objectives of the campaign were achieved through:

- The introduction of special legislation drafted and approved before the campaign was launched, and added to as necessary during its implementation;
- The establishment of special groups in the application of the various campaign measures including the organization of teams responsible for the extension services, for the elimination of dogs, for the registration and examination of dogs, and for the inspection of slaughterhouses;
- Study of the various statistical data collected continuously from slaughterhouses, dog examinations, hospitals, etc.

It was a characteristic of the organization of the campaign that all the members of its various teams worked specifically and solely against echinococcosis. These units specially set up for the campaign thus formed a miniature service under the Director, with specific duties aimed at the eradication of the disease; thus full cooperation between the various teams of the campaign was ensured.

At each District and Rural Veterinary Station (18 stations in all) a group was available solely for echinococcosis activities under the direction of a veterinarian, who in turn was accountable to the Director at Headquarters. These groups were responsible for the implementation of the campaign throughout the island. The veterinarian in charge of the echinococcosis group at these offices supervised and gave day-to-day instructions to the employees in accordance with the policies approved for the campaign. The veterinarians in charge of the groups met the Director once a month, or whenever necessary, to discuss any problems they were facing during the carrying out of their duties.

In 1975 an echinococcosis laboratory was also set up to assist in the technical work of the campaign. At this laboratory cysts from young animals, especially those under two years of age, were examined to determine whether or not they would be capable

Public information: a lecture being given to policemen

of causing infection had they been eaten by dogs, that is to say, whether or not they were "fertile" or "non-fertile". From studies made at the laboratory it was concluded that, while 80 percent of cysts in sheep and 60 percent in goats were fertile, almost none were fertile in the case of cattle and pigs.

The laboratory also closely studied the local cestode involved, *E. granulosus*, and undertook experimental infections of dogs and other animals.

Implementation of the campaign

Stray dog elimination

Before any other control measure could be taken the elimination of all stray dogs had to be given priority. Special teams, suitably equipped, were set up to eliminate strays. Permission was obtained from the Government for these groups to carry special weapons for this purpose. Each weapon consisted of a 50-calibre, aluminium alloy syringe that instantly injected, on impact, a volume of 1-15 ml of lethal liquid by means of a powder charge. Propulsion of the syringe was accomplished by a CO_2-powered pistol or rifle. In 1971, 52 such weapons were purchased. Elimination teams were stationed at all veterinary stations and each was responsible for and covered a certain area of the island; in this way the whole of the island was covered. The teams used off-road vehicles for transport purposes.

From the earliest days of the campaign complaints and protests arose. They came mainly from dog owners who allowed their dogs to wander freely in the streets and who, in general, were not looking after them properly.

The teams covered the countryside and continuously visited all areas in which there was the slightest possibility of finding a stray dog. These areas included places where the refuse from the towns was dumped; places where animals were slaughtered; grazing grounds and, when necessary, mountain and forest areas where stray dogs sometimes took refuge. The teams were also responsible for ensuring that sheep and dogs did not evade the control of their shepherds. The law on this point states that a dog must always be "under the direct control" of

An information group ready to start its daily work

the shepherd. If an extermination team found a dog wandering beyond a certain reasonable distance from its shepherd and not under his "direct control" then the dog was destroyed.

The teams responsible for the elimination of strays in the inhabited areas were on continuous duty in those areas since it was found that some dog owners let their dogs loose during the evening and early morning, and confined them inside their homes or yards only during the day when they thought the elimination teams might be on patrol.

Slaughter control

Prior to the campaign, butchers and other individuals slaughtered animals wherever they thought fit. This might be in the home yard or under a tree by the roadside, the discarded viscera being thrown in nearby fields and thus becoming available for stray dogs. This situation had to be changed at all costs. Responsible officers visited village communities and investigated existing slaughter facilities. Discussions were held with the village authorities and any changes needed in the slaughterhouse of the village were indicated to them. The slaughterhouse had to be dog-proof (i.e., wire-fenced) and an incinerator or a pit had to be available for offal disposal. If, for any reason, improvement to the slaughtering arrangements was slow to be implemented at a particular village, slaughtering at that village was prohibited until the requirements under the law had been met.

Any person slaughtering outside the abattoir was prosecuted under the law. Butchers had to state the day and time when they would be slaughtering in order that one of the campaign meat inspectors could be present so that he could supervise slaughtering and ensure that the butcher properly destroyed any rejected offal.

Informing the public

The public, and especially those more closely associated with the problem, had to be informed on the various aspects of the control effort, so that they understood the dangers involved in the continuation of old established habits and the need for drastic changes. They had to know how they themselves contributed to the problem and

what they ought to do in order to help check the disease. Personal visits were paid to butchers, shepherds and farmers. Special groups of young, well-educated female helpers visited the villages and paid house-to-house visits to discuss the dangers of dog ownership, the seriousness of the disease, etc. Group lectures were given at the village coffee-shops. A quarterly "Anti-Echinococcosis Bulletin" was sent to all the schools, to doctors and to clubs, etc.

Dog testing

After the elimination of most of the stray dogs, examination of dogs for *Echinococcus* tapeworm was started. District testing teams, each using a well-equipped mobile laboratory, established examination centres at suitable sites not far from a village or a group of villages. Dog owners were personally contacted by mail, as well as requested by radio and television, to bring their dogs to the examination centre on a stated day. The village president (mayor) was also requested to help in ensuring that all the dog owners in his community brought their dogs for examination.

The six mobile testing units formed followed scheduled routes and all the dogs on the island were tested. The first test started in June 1972 and ended in December 1972. As from 1973 all island dogs were examined three times a year, with an additional examination being conducted in heavily infested areas. All infected dogs were destroyed with the consent of their owners. Any person not taking his dog for testing was legally prosecuted. Arecoline hydrobromide was used and the collected faecal sample examined by the flotation pan method.

The flotation pan method of examination consists of adding 200 ml of water and 3-5 ml of kerosene to the faecal sample. The mixture is then heated for five minutes. The sample is strained carefully through the screen of the flotation pan, which consists of an outer chamber and an inner chamber having a screen mesh bottom. The pan is lowered into a saturated NaCl solution and moved up and down to detach the parasites from the screen. The inner chamber is allowed to fill, and the salt solution that then overflows into the outer chamber carries with it any parasites present. The solution is then poured into a tray and examined for tapeworms.

Collection of statistical data

Data recorded from the start of the campaign included:

- The number of infected carcasses of each age group for each kind of animal slaughtered;
- The infection rate in dogs (according to use, age, breed, sex);
- Activities undertaken in informing the public (house-visits, group lectures, school lectures, etc.);
- The number of bitches spayed and stray dogs exterminated, etc.

These data were collected frequently (in some cases daily) and sent to the statistical service at Veterinary Headquarters where they were processed.

Results of the campaign

Dog control

Stray dog elimination. Between 1971, when the scheme for elimination was started, and 1978, 62 081 stray dogs were destroyed. About 20 percent of the above number were unwanted puppies. In 1971 alone, 27 552 dogs were destroyed, i.e., 75 dogs per day. In 1972 the number was 15 318 and in 1973, 7 317. Since then between 1 500 and 2 000 dogs have been eliminated annually. The dog population prior to 1971 was estimated at 46 000. It

TABLE 1. **Infection in dogs, 1972-78**

Year	Examination	Number of dogs examined	Number of dogs infected	Percentage infected
1972	First	12 213	833	6.82
1973	First	9 940	279	2.81
	Second	7 842	167	2.13
	Third	8 660	287	3.31
1973 Total		9 940	733	7.37
1974	First	8 611	207	2.40
	Second	6 811	74	1.09
	Third	2 773	20	0.72
1974 Total		8 611	301	3.50
1975	First	3 838	58	1.51
	Second	2 876	35	1.22
	Third	2 834	62	2.19
1975 Total		3 838	155	4.04
1976	First	4 809	47	0.98
	Second	3 947	42	1.06
	Third	4 414	21	0.47
1976 Total		4 809	110	2.29
1977	First	7 110	22	0.31
	Second	6 101	22	0.36
	Third	6 502	9	0.14
1977 Total		7 110	53	0.75
1978	First	9 055	18	0.20
	Second	7 894	17	0.22
	Third	7 666	17	0.22
1978 Total		9 055	52	0.57

TABLE 2. **Infection level of slaughtered animals**

Percentage

Kind of animal	Prior to 1971	1971	1972	1973	1974	1975	1976	1977	1978
Sheep under 2 years of age	6.0	2.3	1.3	0.03	0.08	0.02	—	—	—
Goats under 2 years of age	2.0	1.4	0.9	0.007	0.08	0.007	—	—	—
Cattle under 2 years of age	4.0	1.8	0.9	0.07	0.20	0.07	—	—	—
Pigs for fattening	4.0	0.8	0.2	0.002	0.03	0.002	—	—	—
Sheep over 2 years of age	66.0	49.6	53.9	30.4	43.4	30.4	24.1	14.9	12.7
Goats over 2 years of age	13.0	14.5	12.5	3.9	4.5	3.9	1.8	0.7	0.3
Cattle over 2 years of age	55.0	38.9	30.6	10.2	21.0	10.2	8.0	4.1	5.6
Boars and sows	33.0	18.6	10.0	4.7	10.2	4.7	0.3	0.3	—

can be stated that the stray dog problem now no longer exists on the island, and a stray dog is rarely seen. As from 1978 shepherd dogs had to be fitted with a head muzzle; otherwise they would be considered strays liable for destruction.

Spaying of bitches. From 1971 to 1978, 6 292 bitches were spayed; this is 786 per year. The proportion of spayed females was about one quarter of the total annual female population, which ranged from 1 500 to 2 000. Owners of unspayed bitches had to pay an annual registration fee of C£8 compared with C£1 for spayed and male dogs. In 1978 spayed females constituted about 38 percent of the total female dog population.

Dog population. By the end of 1973, the total dog population was 9 673 (8 023 males and 1 660 bitches) compared with about 46 000 before the stray dog elimination campaign was initiated. In 1978 there were 12 011 dogs (8 058 males and 3 953 females, including 1 529 spayed females).

Infection of dogs. Table 1 gives the number of dogs examined, and the number and percentage found infected from the first examination in 1972 to the third examination in 1978. Three examinations were conducted annually.

The yearly incidence of the disease in dogs was 6.82 percent in 1972, 7.37 percent in 1973, 3.50 percent in 1974, 4.04 percent in 1975, 2.29 percent in 1976, 0.75 percent in 1977 and 0.57 percent in 1978. Between 1972 and 1978 there was a reduction in the incidence of the disease of 91.6 percent.

In 1972 shepherd dogs made up 58.9 percent of the total number of dogs found infected. In the same year hunting dogs made up 34.6 percent and pet dogs 6.5 percent. By 1978 the respective percentages were: shepherd dogs 88.5 percent, hunting dogs 9.6 percent and pet dogs 1.9 percent.

Slaughter control

Abattoir control. In all, there are now (1979) about 200 licensed small abattoirs (other than the large municipal abattoirs, of which there is one in each city) given permission to operate. These abattoirs conform to all the necessary conditions as laid down in the relevant legislation. Home and roadside slaughter are no longer practised. Anyone found trespassing at the abattoirs is legally prosecuted. Each year, the following approximate numbers of carcasses are inspected in these abattoirs: 180 000 lamb, 24 000 sheep, 130 000 kid, 20 000 goat, 190 000 hog and 7 000 bovine carcasses.

Infection in farm animals. Table 2 gives the infection level in the various kinds of farm animals as evidenced by meat inspection at the abattoirs.

Infection levels prior to 1971 were recorded from meat inspection performed at the municipal abattoirs at various intervals in the past. By 1976 infection in young animals was nonexistent. This is evidence of the fact that the environment had been cleared of *Echinococcus* eggs. In sheep over two years of age infection dropped from 66 percent prior to 1971 (when the campaign started) to 12.7 percent in 1978, i.e., a reduction of 81.1 percent. From special surveys it was observed that the majority of sheep in this age group were aged over six or seven years, and thus were animals born prior to or during the first stages of the implementation of the campaign. The same is true of mature goats and cattle. In goats infection dropped from 1.30 percent in 1971 to 0.3 percent in 1978, i.e., by 98 percent. In cattle the respective figures were 55 percent and 5.6 percent, representing a reduction of 90 percent.

Infection in people

Hydatid disease was very common among Cypriots of all ages. There was no village without a known victim and in some families two or three members were infected. Instances of multiple surgery were common. Over a period of 33 consecutive years (1936 to 1968) the annual surgical incidence was 12.8 per 100 000 of the population. This figure was inferred from data in the Archives of the Medical Department. In 1967, 17 cases were reported by the Medical Department, giving an incidence of 3.2 per 100 000. In 1977 there were 7 cases or 1.4 per 100 000 giving a reduction of over 92 percent. This reduction is most evident in young people, among whom the disease is no longer found. ■

Service ability and semen production of buffalo bulls

S. Wierzbowski, M. Nazir, F.B. Hamblin and M. Shafi

The results recorded in this article were obtained from work undertaken at the Semen Production Unit, Qadirabad, Directorate of Livestock Production and Artificial Insemination, Punjab Province of Pakistan. This work formed part of a project assisted by FAO/UNDP for strengthening livestock production, extension and artificial insemination services in the Punjab.

Although famous for its breeds of zebu cattle and buffaloes, the Punjab is now deficient in livestock products. This gap between supply and demand continues to widen. The project is one of the deliberate efforts made by the Government to improve livestock production in the Province.

The results reported are of considerable interest and importance since, as mentioned in the article, quantitative data concerning service ability and semen production of buffalo bulls used in routine AI *operations are virtually non-existent.*

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Based on data presented at the FAO/SIDA/Government of India Seminar on Reproduction and Artificial Insemination of Buffaloes (Karnal, India, 4-15 December 1978), the total number of buffaloes in the world being artificially inseminated at present can be estimated at around 100 000. A growing interest in the practical applications of artificial insemination (AI) of buffaloes has prompted this paper presenting data collected on a routine basis at an AI centre producing primarily buffalo semen.

Quantitative data concerning the libido and service ability of large numbers of buffalo bulls in AI are virtually non-existent. There is, however, an abundance of information on semen characteristics but this is so variable that it is very difficult to deduce from it a distinct pattern in the reproductive capacity of buffalo bulls.

The data presented in this article were collected over a one-year period of routine operations of the Semen Production Unit (SPU), Qadirabad, Pakistan. SPU Qadirabad was established in 1972 and since 1974 frozen semen has been produced utilizing only 0.5 ml straws.

The buffalo bulls used most were

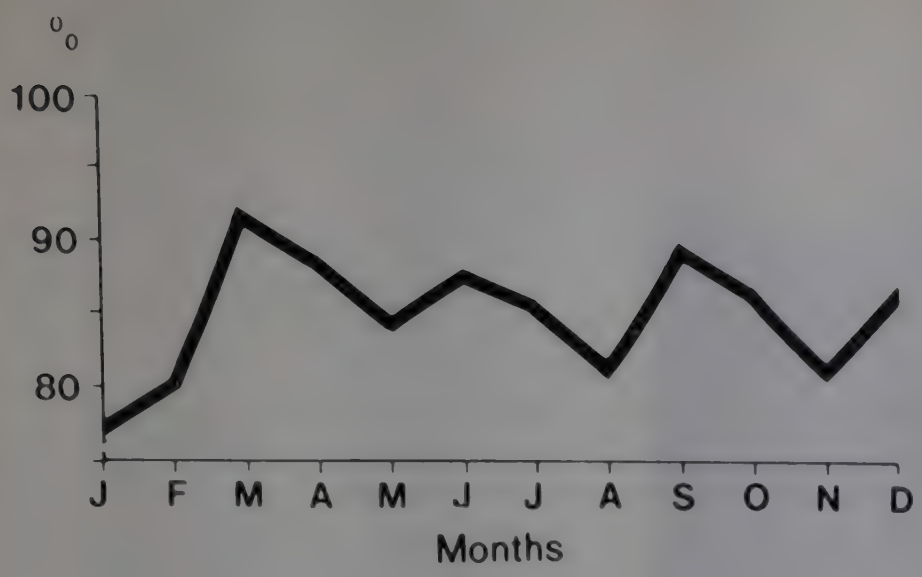

Figure 1. *Level of sexual activity. The percentage of the successful semen collections out of all attempted collections was used to evaluate the sexual activity of the buffalo bulls used in one year of routine work.*

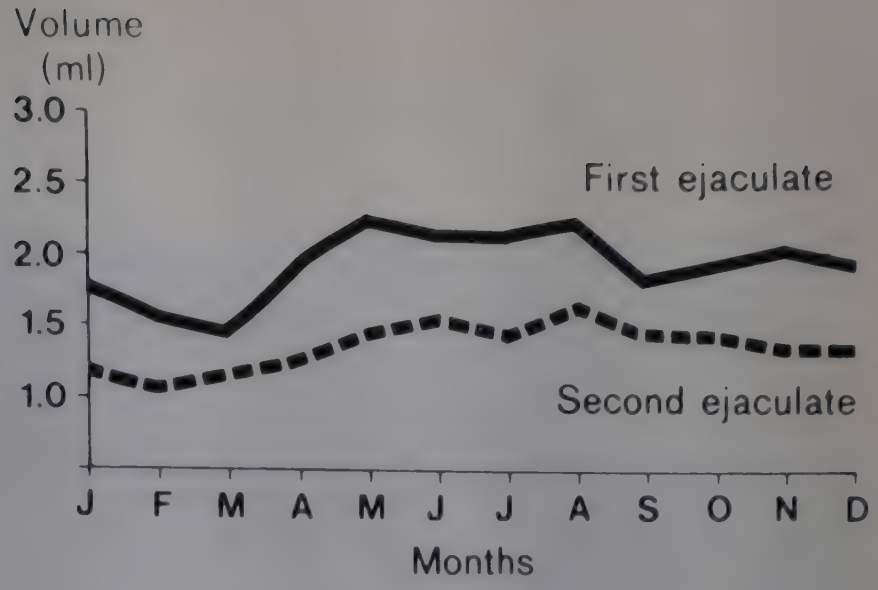

Figure 2. *Monthly averages of number of collected ejaculates (30.6 bulls; 277.5 ejaculates).*

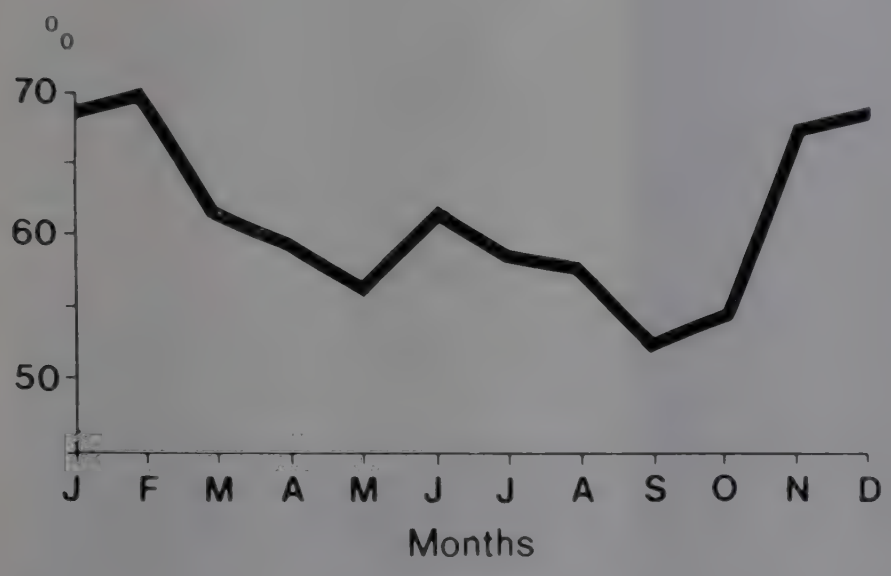

Figure 3. *Monthly averages of percent of collected ejaculates approved for processing (30.6 bulls; 277.5 ejaculates).*

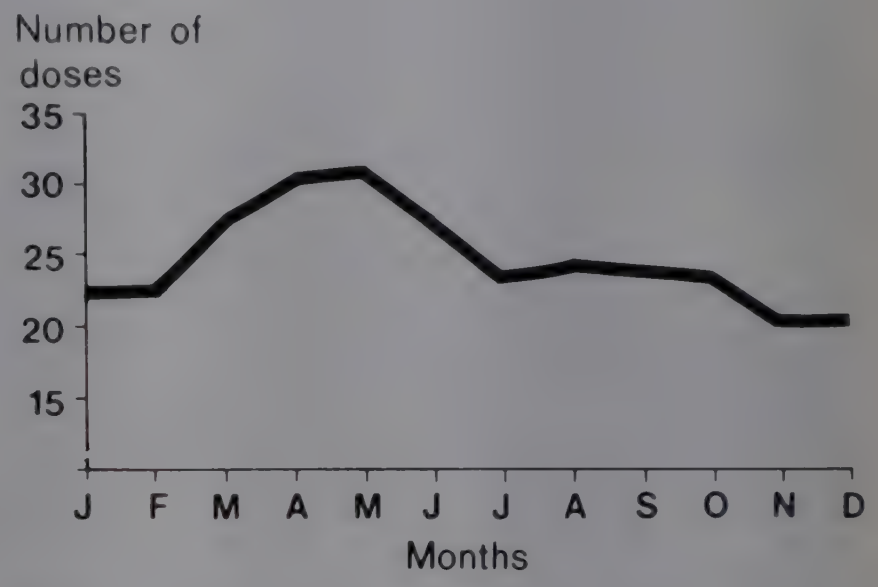

Figure 4. *Monthly averages of semen doses approved for use (30.6 bulls; 277.5 ejaculates).*

50 animals of the Nili-Ravi breed. A monthly average of 30.6 bulls were available but only 22 of these were used as regular semen-producers throughout the year.

The semen was to have been collected twice-weekly from every bull but this plan was not strictly implemented. Collections were carried out in an open space, and usually between 6 and 10 a.m., depending on the season. Teaser bulls were kept in stands, slow-reacting bulls being exposed to stimulation by two or three teasers kept in different places. Non-pressurized vaginas at temperatures of approximately 42-46°C were used. Attempts were made to collect two ejaculates from each bull in use on the collection day.

Semen collection attempts. During the year studied a total of 5 394 semen collection attempts were made, but semen was obtained only in 3 330 (62 percent) of the collection attempts. The collection of the first ejaculate was slightly more successful (67 percent) than the collection of the second ejaculate (56 percent). Libido was seen to decrease between March and September, with the best performance occurring between November and February; this coincides with the natural breeding season of the buffalo (see Figure 1).

Differences between bulls as regards number of successful semen collection attempts were marked. Of the 22 bulls used regularly over the whole year the best performer was successful in 167 (95 percent) of 176 attempts, the slowest being successful in only 51 attempts (31 percent).

Semen volume and number of collected ejeculates. Compared with cattle (both *Bos taurus* and *Bos in-*

Collecting semen

dicus), buffalo bulls yielded ejaculates of distinctly lower volume. The average volume of 3 330 ejaculates collected from 50 bulls was 1.7 ml. The average of 1 814 first ejaculates was 2 ml and of 1 516 second ejaculates 1.4 ml. Very commonly the volume of ejaculates was only 0.25 or 0.5 ml. However, ejaculates of 8 and 12 ml were also recorded.

The average monthly volumes of collected ejaculates indicated a slight seasonal variation with the highest volume occurring between May and August and the lowest between January and March (see Figure 2).

Differences between individual bulls in average volume of ejaculate were also clearly visible. The highest average ejaculate volume of one bull was 2.95 ml (131 ejaculates) and the lowest 0.94 ml (163 ejaculates). On average 115 ejaculates were collected per bull during the year with a range varying from a few ejaculates from some bulls to a maximum of 167 from the best bull.

Evaluation of ejaculates for processing. Evaluation of semen was based on microscopic examination. Ejaculates with a motility of 2 and above in a 5-grade scale and a density of minimum 2, also in a 5-grade scale, were approved for processing. Of the 3 330 ejaculates collected, 2 834 (85 percent) were processed. There was no difference between the percentages of the first and second ejaculates approved for processing. Although some fluctuation was noticeable during the year, no seasonal variations were observed (see Figure 3). However, there were distinct differences between bulls as regards average number of ejaculates qualifying for further processing. With the best bull 99 percent of 163 ejaculates were approved while with the poorest 66 percent of 134 ejaculates were approved.

Number of semen doses produced. The dilution ratio was determined on the basis of microscopic estimation of motility and density. The number of doses from one ejaculate averaged 25. An increase in the number of semen doses per ejaculate was observed from

March to June with the peak occurring in May (see Figure 4).

The number of semen doses per bull averaged 2 363 per year. This was calculated on the basis of an average of 30.6 bulls used each month. However, the number of frozen semen doses actually available for distribution was lower because of selection carried out after freezing, using 40 percent motility as a minimum standard acceptable for use. The efficiency of the bulls varied greatly. Of the 22 bulls used regularly for the whole year the best bull produced 4 952 doses while only 570 doses were obtained from the worst bull.

Concentration of spermatozoa. As mentioned previously, semen concentration was evaluated on the basis of microscopic examination. However, more accurate assessment of the concentration became possible when the semen-counting photometer (IMV) was put into routine use. In three months a total of 425 ejaculates were counted. The average concentration was 1 063 000/mm^3 with a range of from 190 000 to 2 140 000/mm^3.

Review of observations. Generally speaking little has been reported about the service performance and semen production of buffalo bulls based on large numbers of observations. What information is available is frequently in disagreement.

As regards libido and servicing ability, for example, there are suggestions that bulls should be used not more than 75 times per year (Lazarus, 1946), otherwise the quality of the semen may be adversely affected. It has also been suggested that one collection per week is optimum (Sayed and Oloufa, 1957). However, Singh and Roy (personal communication) observed that daily collection of two ejaculates over a period of 42 weeks had no influence on semen quality and libido. Similar observations were made at the Indian Veterinary Research Institute (IVRI) after a twice-weekly scheme of collection had been in use for three years (Bhattacharya, 1974).

The level of the bulls' libido seems to be one of the most important factors determining the efficiency of semen production in the buffalo bull. In the Semen Production Unit studied 67 percent of the scheduled first attempts were successful but only 56

Exercising buffalo bulls at SPU Qadirabad

In addition to its other qualities the buffalo is renowned for its docility as demonstrated by one of bulls at SPU Qadirabad.

percent of the second. It was planned to collect semen twice weekly but in practice 1.7 collections were made on average per week. Two collections weekly, each of two ejaculates, may represent too high a demand on a buffalo bull's service potential. Because of the wide range of responses observed in this species it would seem wise to decide the number of collections per week on an individual basis. For example, a plan for one weekly collection of two ejaculates as a minimum for slow bulls and two weekly collections for bulls with high libido might be followed.

There can be little doubt that, on average, the volume of the ejaculate of buffalo bulls is 1.7 ml or very close to it. Similar observations were made by Bhattacharya and Prabhu (1955), who recorded 1.79 ml, and Chaudhary and Gangwar (1977), who recorded 1.64 ml. However, much higher volumes have also been recorded. Ahmad *et al.* (1964) recorded 3.4 ml, Joshi *et al.* (1967) 2.8 ml to 3.5 ml and Sharma and Vankitasubramanian (1975) 3.8 ml. In most of these latter observations a small number of bulls was used, and preselection for semen quantity and quality may have been carried out.

Individual differences among bulls are marked and this is probably the reason for differences found when a limited number of bulls are studied. Saji (1978) suggested that there was a direct relationship between volume and semen collection frequency. When an average of 2.8 ejaculations was collected weekly the volume was 2.5 ml but when the frequency increased to 3.28 ejaculates per week the volume decreased to 1.92 ml. Saji made a similar observation concerning sperm concentration, which he noted dropped from 845 to 800 million per ml with the above collection pattern.

A number of observations support the view that there is a seasonal effect on the volume of buffalo semen. These include the studies of Patel (personal communication) and Chaudhary and Gangwar (1977), which are in agreement with the present authors' observations made at Qadirabad. However, such an effect was not found by Kushwaha *et al.* (1955) and Ahmad *et al.* (1964).

Surprisingly enough, in view of the subjective methods applied, the estimations of motility given by different authors seem to be in agreement. Using a scale ranging from 0 to 5, Roy (personal communication) reported an average motility of 2.5 and Sengupta *et al.* (1963) in Murrah breed semen between 2.3 and 2.9. At Qadirabad average motility has been estimated at 3.1, individual variations in bulls ranging from 2.5 to 3.9. For semen collected from Egyptian buffaloes, Hafez and Darwish (1956) have reported an average motility score of 7.25, using a scoring range of 0 to 10.

It can be accepted that the average spermatozoa concentration in buffalo ejaculate is close to one million per ml. Shukla and Bhattacharya (1949) and Kushwaha *et al.* (1955) observed that the concentration of spermatozoa in buffalo semen varied between 631 and 1 034 million/ml. Mahmoud (1952) reported a wide range of variation in spermatozoal concentration in the Egyptian buffalo (210 million to 2 000 million/ml) while Madatov (1956) found an average concentration of 980 million/ml. Sengupta *et al.* (1963) found an increase in concentration in winter and spring (1 352 *vs* 1 381 $\times$ 10^6) compared with summer, rainy and autumn periods (1 228, 1 065, 1 040 respectively). Ahmad *et al.* (1964) recorded an average of 1.41 $\times$ 10^9 per ml; Joshi *et al.* (1967) 756 to 1 273 $\times$ 10^6 per ml; and Chaudhary and Gangwar (1977) an average of 1 185 $\times$ 10^9 per ml. Thus, while some differences are noticeable, the concentration of buffalo semen seems to be about one million (or slightly more) per ml.

In view of the factors discussed that are involved in service efficiency and semen characteristics it is not surprising that in the present study the average production of diluted semen, before freezing, was only 2 363 doses per bull per year and the range between individual bulls from 570 to 4 952, since only 22 bulls were used regularly the whole year round. Such a wide range indicates the need for selection of the bulls for their sexual efficiency. At SPU Qadirabad the average frozen semen production for the years 1973-76 was 1 774 semen doses per bull per year (Saji, 1978).

A field in which further research and practical work is necessary is the improvement of methods of freezing buffalo semen. Owing to the inefficiency of current methods, as well as to differences in semen freezability and in the ejaculates of the same animal shown by some individuals, the numbers of doses of frozen semen produced were reduced by some 40 percent after the check on motility and freezing had been performed. Another point requiring clarification is the optimal number of live sperms in doses of frozen semen. No information has so far been made available on this point. The SPU Qadirabad practice of calculating dilution to give an average of 25 $\times$ 10^6 live spermatozoa per frozen semen dose may well provide economies compared with dilutions commonly adopted for use with cattle.

Conclusions. The conclusions reached as a result of the work so far done at Qadirabad may be summarized as follows:

First, weak libido, small quantities of semen and frequently poor semen quality make the buffalo bull a less efficient semen producer and a more difficult subject in AI than *Bos taurus* and *Bos indicus* bulls.

Second, the wide range of individual variation in all aspects of service ability indicates the need for the selection of buffalo bulls for use in AI. This appears to be the basic condition for improving the effectiveness of buffalo semen production for AI.

Third, improved methods of freezing semen and evaluating its fertility seem to be the main directions in research and practical work, which are necessary if progress in the further development of AI for buffaloes is to be achieved. ■

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Milk replacers for calves and lambs

R. Toullec, M. Theriez and P. Thivend

Until recent years milk replacers were essentially made up of cow's milk in which fatty substances were replaced with more economical sources of energy (substitute lipids, powdered milk, whey and starchy products). The next stage in the preparation of these feeds consisted in replacing dried skim milk with other, less costly sources of protein for the preparation of synthetic milk. This did not appear very advisable in certain countries, such as those of the European Community, because of the important role of milk replacers in regulating the market for milk products. However, this is not the general situation, as many countries have to reserve the maximum amount of milk for human feeding.

In the present article, the main aspects of lipid, carbohydrate and protein digestion will first be described, after which energy utilization and protein, mineral and vitamin requirements will be discussed. Finally, recommendations that may be made at present for the preparation of milk replacers will be examined. Throughout this text a distinction will be made between two types of animals:

- Calves for slaughter, liquid-fed from birth until the age of three to five months;
- Calves and lambs for breeding, which receive these feeds only for short periods (lambs, about six weeks; calves, about two months) since they must ingest dry feeds as soon as possible (fodder or concentrates) or grass.

Digestion

Milk and milk replacers pass directly into the abomasum by means of the closure of the oesophageal groove (Ørskov and Benzie, 1969; Guilhermet *et al.*, 1975). Food is then digested by pre-ruminant processes. Pre-ruminant calves and lambs depend much more than ruminants on the qualitative value of their ration, especially of its protein fraction and, to a lesser extent, on the nature of the energy.

LIPIDS. Alimentary triglycerides undergo a hydrolysis in the rennet under the action of the pre-gastric esterase secreted by the salivary glands (Otterby *et al.*, 1964; Toullec and Felinski, 1971). In the calf (100-kg liveweight), total pancreas lipase activity is weak at birth, triples at about eight days, with little development after that (Huber *et al.*, 1961). In the lamb, however, lipase activity decreases from birth to the age of two days, remains stable until the age of three weeks and then increases. Bile does not contain any enzyme but has an important function in lipid digestion; however, nothing is known about its secretion in relation to age and dietary regime. The unsaturation of food lipids is not altered in the course of digestion and absorption and therefore has a strong influence on the unsaturation of body fats (Toullec and Mathieu, 1969; Aurousseau *et al.*, 1973).

In the calf lipid digestibility depends upon the quantity ingested, at least until the age of three weeks, when the calf is not able to absorb more than 5.4 g of fatty matter in milk per kg of liveweight per day (Mylrea, 1966). In both species digestibility also varies according to the nature of the lipids (Table 1). The differences in digestibility depend on the fatty acid components and the glyceride structure of the fats. Digestibility of fatty acids decreases as the chain lengthens, but it increases with the degree of unsaturation; the digestibility of long-chain saturated fatty acids is higher when they are placed within the triglyceride molecule (Toullec and Mathieu, 1969; Walker and Stokes, 1970; Hamilton and Raven, 1973). This appears to be due to the formation of insoluble calcium compounds by the long-chain saturated fatty acids, if they are in an external position.

However, the digestibility of rapeseed oil, which has long-chain saturated acids, is very low in both species owing to its high content of erucic acid, which, although unsaturated, is very little absorbed by the animal (Walker and Stokes, 1970). Differences in digestibility arising from the nature of the lipids are much greater in the calf under one month of age than thereafter: for example, between 15 and 25 days of age, coconut oil may have an apparent digestibility 25 points higher than that of tallow, whereas between 25 and 95 days the

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TABLE 1. **Digestive utilization of lipids by the pre-ruminant calf and lamb**

Factor	Content in feed (% DM)	Apparent digestibility (%)	Reference
Source of fat [1]			
Fat in milk	21	97.5	Toullec and Mathieu (1969)
Tallow	20-24*	90.4-91.1*	
Pig fat	20-29*	96.0-88.4*	Walker and Stokes (1970)*
Hydrogenized herring oil	20	93.9	
Coconut oil	20-24*	95.5-96.4*	Aurousseau *et al.* (1973)*
Palm oil	17-24*	95.0-92.2*	
Peanut oil	20-29*	93.2-97.8*	Bell and Adams (1974)
Rapeseed oil	15-30*	69.0-59.4*	
Glyceride structure [1]			
Non-interesterified tallow	20	88.7	Hamilton and Raven (1973)
Interesterified tallow	20	93.1	
Mode of incorporation			
Whole dried milk	20	95.2	Raven and Robinson (1964)
Melted butterfat	20	71.8	
Effect of emulsifiers			
Tallow oil [2]			
Alone	15	87.2	Toullec and Mathieu (1970)
+ 2.4% saccharoglycerides and 1% lecithin	15	92.7	
Tallow oil introduced wet in skim milk [3]			
Alone	19	89.1	Toullec (unpublished results)
+ 4% saccharoglycerides and 1% lecithin	19	87.7	
Incorporation level [1]			
Tallow oil	27	92.8	Toullec and Mathieu (1971)
Tallow oil	32	93.7	
Source of protein			
Tallow oil + insoluble fish-protein concentrate [4]	19	78.2 (82.7)	Toullec *et al.* (1974c)
Tallow oil + soluble fish-protein concentrate [4]	18	91.1 (90.1)	
Tallow oil + skim milk alone [1]	18	91.4 (93.3)	Van Weerden (1974)
Tallow oil + skim milk (67%) and insoluble fish-protein concentrate (33%)	20	84.2 (86.5)	

NOTE: * = Data for the lamb; DM = dry matter; DUC = digestive utilization coefficient. The figures in parentheses show the apparent DUC of nitrogen in feeds. [1] Homogenized fat in concentrated skim milk. — [2] Protein source: dried skim milk. — [3] Feed protein sources: milk yeasts (50 percent) and dried skim milk + synthetic amino acids (50 percent). — [4] Homogenized fat in mixtures of fish-protein concentrate and ultrafiltrated milk whey.

difference is only 3 points (Toullec and Mathieu, 1969).

In the lamb liveweight at birth has an effect on energy digestibility, and, more particularly, on that of lipids. During the first week of life of a lamb, each kilogram under the average birth weight results in a decrease of 2 points in the digestibility of palmitic acids and of 6 points in that of stearic acid; however, the digestibility of shorter-chain or unsaturated fatty acids is not affected (Houssin, unpublished).

Whatever the age, emulsion quality has a strong effect on lipid digestibility. Fats are usually more digestible when homogenized in concentrated skim milk (i.e., in liquid form) than when they are powdered, ready-pulverized feed constituents (i.e., in dry form). This is because it is not possible to obtain such fine particles and such a stable emulsion with the latter procedure. Addition of emulsifiers improves the digestibility of fat incorporated in dry form, and has little effect otherwise, except on the very young calf (Raven and Robinson, 1964; Ladrat and Jousselin, 1965).

The rate of incorporation into the feed has little effect on digestive utilization; very high proportions (over 25 percent in calves and 35 percent in lambs) do increase the frequency of diarrhoea, however. The substitution of less-digestible nitrogenous matter for milk proteins may have a depressing effect on the digestive utilization of lipids.

CARBOHYDRATES. The calf's glycolytic enzymatic equipment is relatively poor. Only intestinal lactase is present in high quantities at birth; its activity tends to decrease with age but remains relatively high in the pre-ruminant calf, at least up to the age of 25 weeks (Toofanian *et al.*, 1973). Lactose hydrolysis is faster than the absorption of its digestive products and should not be a limiting factor for its utilization (Coombe and Smith, 1973). Amylolytic activity of the pancreatic juice is low at birth but increases up to the age of two months (Ternouth *et al.*, 1976) and increases when feed is enriched with glucose (Thivend, 1976). No evidence has been found of salivary amylase (Flipse *et al.*, 1950), of intestinal saccharase (Dollar and Porter, 1957) or of oligoα(1-6)glucosidase (Capdeville *et al.*, 1967) in the calf.

Caecum and colon microorganisms also have an important function in the digestion of sucrose and starchy sub-

stances; volatile fatty acids and lactic acid may make up as much as 60 percent of digestible starch energy (Assan, 1974). This microbial digestion is useful — provided, however, that it does not become excessive or give rise to diarrhoea.

Lactose, maltose and glucose have very high digestibility (96 to 99 percent), whatever the quantities ingested. As long as the feed has a normal lipid content, the calf can digest up to 12 g of hexose-equivalent/kg liveweight/day [hexose equivalent = (glucose weight + lactose weight) × 1.05] (Roy, 1970). Sucrose, however, is poorly utilized. Digestibility of starches (Table 2) varies according to their origin (e.g., cereal starches are more digestible than those of tubers) and the technological processing to which they have been subjected (pre-gelatinization, dextrinization, enzymatic hydrolysis), which have a predominantly favourable effect in the case of starches difficult to hydrolyse when raw, such as the starch of potatoes. Digestibility increases with age up to two months but decreases if the proportion of raw starch in the feed exceeds 15 percent.

Carbohydrate digestion has been studied much less in the lamb than in the calf. In 1959 Walker demonstrated the presence in the lamb of the main glycolytic enzymes (pancreatic and intestinal amylases, intestinal maltase and lactase). As in the case of the calf, the lamb has no invertase (Walker, 1959; Mayes and Ørskov, 1974). No clearly defined development of glycolytic enzymatic activity during growth in relation to liveweight has been observed (Walker, 1959), but it does seem that pancreatic amylase increases, especially between the ages of 2 and 14 days (Corring and Guilloteau, unpublished results).

Until very recently it was thought that the lamb did not digest starch well. It is now known, however, that digestibility of raw maize starch is very high in the young lamb (98 to 99 percent at the age of three to four weeks) and that this digestion is essentially enzymatic (Peyraud and Thivend, 1979). Similar results have been obtained with starch from pre-gelatinized maize (Soliman *et al.*, unpublished).

PROTEINS. In the lamb (liveweight 100 kg) the amount of chymosin present in the mucosa of the abomasum increases between birth and two days of age but then decreases until the age of six weeks; the amount of pepsin present develops similarly to that of chymosin during the first week, but then increases during the following five weeks (Guilloteau *et al.*, unpublished). In the calf the total amount of chymosin present in the contents of the abomasum does not seem to change with age, while that of pepsin increases (Garnot *et al.*, 1977); the amounts of hydrochloric acid and pancreatic proteolytic enzymes in the abomasum are low at birth and increase mainly during the first month (Ternouth and Roy, 1973). Treatment of skim milk with excessive heat, as well as its replacement by certain substitute proteins may have unfavourable effects on the secretion of hydrochloric acid, chymosin, pepsin and/or pancreatic proteolytic enzymes as well as on the degree of proteolysis in the abomasum (Ternouth and Roy, 1973; Guilloteau *et al.*, 1975; Williams *et al.*, 1976; Garnot *et al.*, 1977).

Digestibility of milk proteins is very high and increases in both species — up to 96-97 percent during the first month after birth (Table 3). In the lamb it is influenced by weight at birth, decreasing by 0.7 point per kg (Houssin, unpublished). Digestibility of milk proteins is usually little affected by drying if this is done by the spray process, although excessive heat treatment may lower it to a considerable degree (Shillam and Roy, 1963). Protein coagulation, which regulates gastric evacuation and the digestion of nitrogenous matter and lipids (Toullec *et al.*, 1971), has a favourable effect on digestibility in the calf up to the age of one month.

Digestibility of substitute proteins in the calf increases during the first month but is in general lower than that of milk proteins. In both species the highest values are obtained with milk whey and fish proteins once they

TABLE 2. **Digestive utilization of carbohydrates by the pre-ruminant calf**

Carbohydrate	Rate of incorporation (% dry matter)	Apparent digestibility (%)	Reference
Glucose	17	99.0	Mathieu and De Tugny (1965)
Maltose	17	96.9	Mathieu *et al.* (1970)
Lactose	38	99.3	Mathieu and Barre (1964)
Sucrose	17	73.4	Mathieu and Barre (1968)
Raw starches			
Maize	17	91.6	Mathieu and Thivend (1968)
Maize	44	65.1	
Wheat	17	94.0	Thivend (1976)
Rice	17	92.9	
Potato	17	59.2	Mathieu and Thivend (1968)
Cassava	17	77.6	
Banana	17	64.9	Assan (1974)
Sweet potato	17	78.8	
Pre-gelatinized starches			
Maize	17	84.1	Mathieu and Thivend (1968)
Potato	17	89.4	
Slightly soluble dextrines			
Maize	17	92.3	Mathieu *et al.* (1970)
Potato	17	84.5	
Wholly soluble dextrines			
Potato	17	77.4	Mathieu *et al.* (1970)
Maize	17	76.9	

have undergone partial enzymatic hydrolysis; the plant proteins so far studied have lower digestibility. Results obtained with soybeans are improved by heating the soybeans (elimination of antitrypsic factors) and elimination of part or all of the carbohydrate fraction.

Energy utilization

In cow's milk and milk replacers proteins constitute a relatively unchanging part of the energy (20 to 30 percent). Lipids and carbohydrates may represent 48 and 27 percent respectively of energy in the case of whole milk with 4 percent fat content and 19 and 54 percent in the case of milk replacers containing 9 percent tallow and 30 percent starchy products.

The composition of milk replacers has an influence on the increase in value of calves for slaughter. An increase in the fat content and decrease in the protein content help increase calf fattening (Van Es, 1970). The substitution of starchy substances for part of the lipids brings about, in male Normandy calves, an increase in the amount of fixed proteins and a decrease in that of fixed lipids (Table 4). The heavier the calves are, the more marked this substitution is, and this demonstrates the value of the final products of the digestion of starchy substances (glucose, lactic acid and acetic acid) (Vermorel *et al.*, 1974).

There are only a few data on the lamb. According to Norton *et al.* (1970) an increase in the protein content of milk reduces the amount of lipids and increases that of fixed proteins.

The net yield of energy from the metabolizable energy consumed in addition to upkeep requirements is about 68 percent in both the calf and the lamb (Vermorel, 1978). This yield seems to be independent of the composition of the feed (protein component, lipid component and nature of sources of energy). These experimental results are in apparent contradiction with current data concerning the respective costs of protein and lipid synthesis.

TABLE 3. **Digestive utilization of proteins by pre-ruminant calf and lamb**

Product	N supplied by product (%) [1]	Apparent DUC percentage N of product to age of animal (weeks) [2]	Reference
Whole milk	100	97.0 (2-14)	Mathieu and Barre (1964)
Spray skim milk			
Normally coagulating	100	91.9 (3) 96.1 (5-14)	Toullec *et al.* (1974a)
Na citrate added [3]	100	87.0 (3) 95.4 (5-14)	
HCl added [3]	100	74.8 (3) 95.0 (5-14)	
Milk whey concentrated by			
Centriwhey method	100	66.5 (3) 90.7 (5-14)	Toullec *et al.* (1974b)
ultrafiltration	100	86.7 (3) 94.3 (4-11)	Toullec *et al.* (1974c)
Fish			
Hexane-extracted fat	81	83.5 (5-14)	Guilloteau *et al.* (1977)
white, partially hydrolysed	73	80.3 (3) 91.0 (5-14)	Paruelle *et al.* (1974)
Soybean			
cooked	75	63.1 (3) 74.2 (5-14)	Paruelle *et al.* (1972)
concentrate (alcohol extraction)	78	79.6 (5-14)	Guilloteau *et al.* (1977)
isolate	100	75 (2) 87 (5)	Porter and Hill (1963)
Yeasts cultivated in			
petroleum-oil	70	76.4 (3) 84.4 (5-14)	Paruelle *et al.* (1972)
milk serum	75	75.1 (4) 79.8 (5-12)	Toullec and Coroller (unpublished)
Bacteria cultivated in methanol	50	90.6 (7-15)	Guilloteau *et al.* (1979)
Potato	74	73.6 (4) 82.2 (5-14)	Toullec and Coroller (unpublished)
Spray skim milk*	100	96.8 (2-4)	Theriez *et al.* (1973)
Milk whey concentrated by Centriwhey method*	50	92.3 (2-4)	Theriez *et al.* (1973)
Partially hydrolysed white fish*	50	92.2 (2-4)	Theriez *et al.* (1973)
Yeasts cultivated in petroleum-oil*	50	90.3 (2-4)	Theriez *et al.* (1973)
Spray skim milk*	100	93.5 (2) 94.6 (3) 96.6 (6)	Theriez *et al.* (1977)

NOTE: * = Data for the lamb; DUC = digestive utilization coefficient.

[1] Percentage of total nitrogen in feed, the rest being supplied by dried milk whey and synthesized amino acids (except in the case of bacteria cultivated in methanol together with dried skim milk and, in the case of substances tried out on the lamb together with dried skim milk and dried milk whey). — [2] When the product studied did not contain all of the nitrogen, DUC was calculated on the assumption that the DUC of the nitrogen in the milk whey or in the dried skim milk had remained unchanged. — [3] The addition of citrate inhibits coagulation under the action of chymosin; the addition of HCl (up to pH 4.25) totally prevents coagulation of casein in the stomach.

TABLE 4. **Effect of replacement of part of the lipids with starchy substances on nitrogen retention and protein fixation**

Content in the feed (% DM)		
Lipids	21	9
Starchy substances	10	27.5
Metabolizable energy intake (Mcal/day)	13.55	13.28
Quantity of lipid intake (g/day)	576	289
Fixed quantities (g/day):		
proteins	253	310
lipids	452	400
$\frac{\text{Palmitic acid}}{\text{Stearic acid}}$ in adipose deposits	1.31	1.03

Source: Vermorel et al., 1974.

Protein requirements

Protein requirements imply a specific need for certain essential amino acids and an overall non-specific requirement of amino acids. The determination of the optimum protein content in feeds is a first approach to the determination of the nitrogen requirement.

QUANTITATIVE REQUIREMENTS. It is difficult to establish the precise quantitative requirements of nitrogenous matter by factorial analysis. It seems better to make a systematic study of the effect of protein introduction on nitrogen retention and growth.

Some results obtained, using different milk replacers containing 16 to 28 percent of proteins processed exclusively from skim milk and casein, with Friesian slaughter calves at liveweights of between 40 and 165 kg are given below (Van Weerden *et al.*, 1970; Van Hellemond, 1970):

- An increase in protein content of over 24 percent during the first four weeks of the fattening period slightly improves nitrogen retention, daily liveweight gain and feeding efficiency; however, this positive effect does not last until the time of slaughter;
- A protein content of 20 percent is too low for optimum results during the first 8 to 10 weeks but seems sufficient beyond that period;
- A protein content of 18 percent is always too low, even at the end of fattening.

For calves to be slaughtered between 145 and 165 kg, the optimum protein content in a feed supplying about 4 500 kcal of metabolizable energy/kg in powder form is estimated at 24-25 percent during the first eight weeks and at 20 percent after that period, when proteins are supplied in liquid form through skim milk. The figure of 20 percent might even be reduced during the finishing period for calves to be killed at higher liveweights, but this remains to be verified. When employing substitute proteins less digestible than those of milk the amounts of these should be increased.

In the lamb a 20 to 30 percent increase in protein content brings about greater nitrogen-retention but has no significant effect on growth (Theriez *et al.*, 1977). The use of two different feeds, one containing 30 percent of protein for the first three weeks, the other less (20 or 25 percent) for the final part of the milk diet, would be the best way to ensure maximum protein-fixation in the lamb during its first weeks of life. This solution, however, is not practical for breeders who only use artificial milk feeding for a small number of lambs. In this case the figure of 25 percent seems to be the most advisable for feeds supplying about 4 900 kcal of metabolizable energy/kg in powder.

Other criteria may be employed to estimate the degree of satisfaction of protein requirements, especially the degree of uraemia and amino acidaemia in the blood. High values for these two parameters indicate incomplete metabolic utilization of feed proteins, while low values indicate an insufficient nitrogen content (Patureau-Mirand, 1975).

QUALITATIVE REQUIREMENTS. It has not been established precisely which amino acids are really essential for calves and lambs, although there are indications that the amino acids are the same as those essential for growing pigs and rats (i.e., threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, histidine, arginine and tryptophan). Cystine and tyrosine, which can be synthesized from methionine and phenylalanine respectively, are thought to be important, but not essential amino acids.

The requirements of amino acids essential for calves and lambs can be estimated by studying variations in amino acidaemia after ingestion of increasing amounts of amino acids

TABLE 5. **Requirements in essential amino acids (EAA) and less-essential amino acids (LEAA) in the pre-ruminant calf and lamb**

Amino acid	Calf [1]		Lamb [2]	
	g/kg$^{0.75}$/day	g/100 g EAA + LEAA	g/day at age 8 days	g/day at age 21 days
Threonine	0.8	10.2	3.1	3.3
Valine	0.9	11.5	4.7	4.9
Methionine + cystine	0.65	8.3	2.6	2.6
Isoleucine	0.85	10.9	3.9	4.1
Leucine	1.3	16.6	6.6	7.0
Phenylalanine + tyrosine	0.9	11.5	—	—
Lysine	[3] 1.3	16.6	6.6	6.6
Histidine	0.4	5.1	—	—
Arginine	0.55	7.0	—	—
Tryptophan	—	[4] 2.2	—	—

NOTE: — = negligible.

[1] Patureau-Mirand **et al.** (1974). — [2] Lamb fed **ad libitum** (Patureau-Mirand and Theriez, 1976). — [3] This value could be lowered to 1.15 in a calf weighing between 155 and 210 kg (Patureau-Mirand **et al.**, 1976). — [4] The value given represents tryptophan in the sum of corrected contents in EAA and LEAA for milk (sum calculated according to Pion **et al.**, 1963: leucine content limited to 1.5 times that of isoleucine; tyrosine + phenylalanine and arginine contents limited respectively to 12 and 7.3 percent of the sum of corrected contents in EAA and LEAA.

TABLE 6. **Mineral element contents in cow's milk and levels recommended for milk replacers**

(g/kg dry matter)

Element	Cow's milk	Milk replacer
Calcium	10	13
Phosphorus	7.5	7
Magnesium	1	2
Potassium	12	10
Sodium	4	4
Chlorine	8.5	8

Source: Gueguen, 1978.

TABLE 7. **Trace element contents in cow's milk and requirements for pre-ruminant calf**

(mg/kg dry matter)

Element	Cow's milk	Calf's requirement
Iron	1.5 - 3.8	40
Copper	0.15 - 1.15	5-10
Zinc	15 -38	50
Manganese	0.2 - 0.4	50
Iodine	0.1 - 0.2	0.12
Selenium	0.02 - 0.15	0.1
Cobalt	0.004- 0.008	0.1
Chromium	0.08 - 0.15	2

Source: Lamand, 1974.

(Patureau-Mirand *et al.*, 1973a,b, 1974 and 1977; Williams and Smith, 1975). If certain essential amino acids are supplied in insufficient quantities their blood levels will be found to be low and relatively constant. If they are supplied in excess they accumulate because their metabolic utilization is incomplete. The optimum supply is that at which the beginning of accumulation can be observed. This holds for all essential amino acids with the exception of tryptophan (not assayed) and phenylalanine, which is known to be very readily transformed into tyrosine.

The requirements in essential and less-essential amino acids found by this method for pre-ruminant calves and lambs under intensive growth (Table 5) show great similarity with those of growing rats and pigs. The requirements of sulphur (S)-containing amino acids can be met with a supply of cystine of up to half of the total requirement. Once requirements of amino acids are known, it is possible to reduce the requirement of protein of known composition.

Proteins in cow's milk are rich in essential and less-essential amino acids (52 g/16 g N)[1] but low on S-amino acids (Pion, 1971). A methionine supplement can improve growth and feeding efficiency in the calf (Odorico, 1969; Robert, 1971). It also improves nitrogen retention in the lamb but has little effect on lamb growth, perhaps because it works mainly on the growth of wool (Patureau-Mirand *et al.*, 1977). A slight deficiency in threonine, isoleucine, lysine and arginine appears to exist in young calves ingesting less than 60 g/kg$^{0.75}$/day of feeds having a protein content below 25 percent. Heat treatment of skim milk may make part of the lysine unavailable. This effect is usually very limited during pasteurization, concentration and spray-drying, unless one of these operations is performed badly; however, it is often important in the case of roller-drying (Van Den Breuel *et al.*, 1972). This explains conflicting results observed with lysine supplements added to milk replacers that are rich in dried skim milk (Toullec *et al.*, 1973). Experiments performed using threonine, tryptophan, arginine and glycine as supplements to powdered milks already enriched with methionine and lysine have not given favourable results (Robert, 1971). It therefore appears that, apart from a verified lack of S-amino acids, good-quality powdered milks are relatively well supplied with the amino acids essential for both species.

Among the other proteins currently included in milk replacers, those of milk whey seem to be deficient in S-amino acids and possibly histidine and arginine. Their concentration by means of hot precipitation or ultrafiltration gives products that are much richer in essential and less-essential amino acids (56 to 60 g/16 g N, instead of 48).

Fish proteins are poor in tryptophan. Their content of amino acids depends on the species used and the technological processing they receive; protein concentrates obtained from white fish by controlled enzymatic hydrolysis contain less of the essential amino acids than Norwegian herring meal (37 g/16 g N, instead of 45). Proteins from soybean and alkane yeasts are rich in essential amino acids (44 and 47 g/16 g N, respectively) but poor in S-amino acids and, to a lesser extent, in threonine and lysine (soybean) or in histidine (yeasts).

Milk yeasts and bacteria cultivated in methanol are less rich in essential amino acids (39 and 41 g/16 g N respectively) than alkane yeasts. Potato proteins have high contents of essential and less-essential amino acids (55 g/16 g N) and seem to be well balanced, with the exception of a slight relative deficiency in lysine and histidine. Used in a combined form, certain proteins (such as those from fish and milk whey) may complement each other. It is important to bear all these facts in mind so as to determine the protein content of the feed and amino acid supplements.

MINERAL REQUIREMENTS. The calf's mineral requirements have recently been studied by Gueguen (1978) (the macro-elements) and by Lamand (1974) (the trace elements).

Macro-elements. Cow's milk seems to be sufficiently rich in all micro-elements, with the exception of magnesium. The lower digestibility of substitute fats leads to the formation of insoluble calcium compounds and thus to a lower calcium digestibility, which is especially noticeable during the first week of life in lambs of low birth weight (Houssin, unpublished results). Recommended additions to milk replacers for calves are, therefore, similar to the levels found in milk, except for magnesium and calcium, which should be supplied in larger quantities (Table 6). Phosphorus and calcium requirements in the lamb are not well known. According to Walker (1972) they should be 7.7 and 9.5 g/kg of dry matter respectively for a 10-kg lamb gaining 200 g/day and lower for animals growing more rapidly. These recommendations apply to milk replacers with a basis of skim milk and milk whey containing about 20 percent of substitute fats. It is likely that the total or partial replacement of proteins for the preparation of synthetic milks has a very bad effect on the digestive utilization of calcium and phosphorus; if this proves to be the case, the amounts to be added should be reconsidered. Calcium and phosphorus additions can also be varied according to the type of milk replacer, bearing in mind that the digestibility of calcium decreases with

[1] Sum of corrected contents in essential and less-essential amino acids (see Table 5).

age of animal when its content in the feed is high (Paruelle *et al.*, 1973).

Trace elements. The pre-ruminant calf can utilize its liver reserves of certain trace elements to overcome alimentary deficiencies in part. Hepatic reserves of iron, copper and iodine depend on the mother's diet during gestation. Contents of certain trace elements in milk are influenced by the amounts ingested by the cow but are usually not sufficient to cover the calf's requirements (Table 7). Metallic cobalt is not quite as important in the pre-ruminant as in the ruminant for the synthesis of vitamin B_{12}. Kirchgessner *et al.* (1968) suggest, however, a cobalt requirement of the order of 1 mg/kg dry matter.

Recommended additions are very close to the calf's requirements, except in the case of iron in milk replacers for slaughter calves (Table 9). The supplement of iron that would be optimal for health, growth and alimentary efficacy would not produce a meat white enough to meet market requirements. The recommendations shown in the table are, however, only an indication.

In certain cases they do not prevent the development of excessive anaemia, which should be treated with supplementary iron (by giving intramuscular injections of dextrane iron or iron-enriched feed for a few days). Bearing in mind the heterogeneous nature of iron reserves in the livers of calves at birth (Charpentier, 1966), it would be wise to treat animals individually in accordance with their haematocrit value.

In other cases the meat is too highly coloured even when milk replacers short in iron are used; this could be caused by uncontrolled intake of iron (in the water used to dilute the milk powder, or from iron objects that the calf may lick, etc.).

As to copper, the level of 10 mg/kg dry matter should not be exceeded if the risk of toxicity is to be avoided. Certain cases of nutritional deficiency may be the result of poor zinc digestibility, which makes it necessary to supply zinc by intramuscular injection (300 mg) (Lamand, 1974).

Corresponding data for lambs are not available. The recommendations suggested for the calf may be applied to lambs but it should be noted that iron-content limits are not the same for this species, which, again unlike the calf, is also highly sensitive to excessive copper.

TABLE 8. **Average vitamin content of cow's milk: requirements of pre-ruminant calf and recommended additions**

Vitamins	Contents in cow's milk/kg of dry matter [1,2]	Calf's requirements		Recommended additions per kg dry matter intake [1,4]
		Per 100 kg liveweight and per day [1,3]	Per kg dry matter intake [1,4]	
Ascorbic acid	120			[5] 100
Thiamine	3.35	1.8-9.5	1.0-5.3	6
Riboflavin	12.2	1.4-4.5	0.8-2.5	3
Niacin	9.5	18-26	10-14	14
Pyridoxine	4.4	3.6	2.0	2
Pantothenic acid	25.9	9-19.5	5-11	12
Folic acid	0.56	1.5	0.8	1
Vitamin B_{12}	0.05	0.02-0.1	0.02-0.055	0.06
Biotin	0.30	0.19	0.11	0.12
Choline	1 080	2 600	1 440	1 500
Vitamin K	0.64	—	—	[5] 2
Vitamin A	11 500	5 350-85 400	3 000-48 000	24 000
Vitamin D	307	400-5 000	220-2 800	3 000
Vitamin E	7.8	18-54	10-30	30-40

[1] Values in mg except for vitamins A and D, which are expressed in International Units (IU). — [2] Causeret (1971) and Alais (1975). — [3] Agricultural Research Council (1965), Roy (1970) and Radostits and Bell (1970). — [4] Calculated on the assumption of minimum consumption of 1.8 kg of DM/100 kg liveweight. — [5] Values estimated from requirements in rats (Pawlak and Pion, 1968).

Vitamin requirements. The calf possesses small vitamin reserves at birth (Roy, 1970). Reserves of vitamins A, E, and B_{12}, as well as the content of these vitamins in the colostrum and in the milk, depend respectively upon the mother's intake of β-carotene and vitamin A, and of tocopherols and cobalt (Agricultural Research Council, 1965; Roy, 1970; and Causeret, 1971). This explains the lower mortality observed in calves of dams that have had vitamin A added to their winter rations (Michel and Dardillat, 1972).

Estimates of vitamin requirements proposed by various authors (Agricultural Research Council, 1965; Roy, 1970; and Radostits and Bell, 1970) varied within very wide limits and were not obtained under conditions of intensive growth (Table 8). The estimates of the vitamin A requirement depend upon the definition of requirement adopted: the lowest estimate is that which should ensure normal growth and the highest that which should give the highest hepatic reserve. Vitamin E requirements increase with the degree of unsaturation of fat in the feed. Requirements for vitamins C and K have not been established precisely but it is probable that the calf, as well as adult ruminants, is able to synthesize them. Niacin deficiency has only been shown with a tryptophan-poor diet.

Recommended additions have been estimated for maximum requirements. However, the value given for vitamin A is that which ensures the maximum plasma content. The values proposed for ascorbic acid and vitamin K correspond to the requirements in the rat. In usual milk replacers, dried

skim milk and dried milk whey contribute significant amounts of most of the water-soluble vitamins. Although the determination of requirements is admittedly imprecise it is advisable to add the quantities corresponding to the additives recommended, especially in the cases of ascorbic acid, thiamine, folic acid and vitamin B_{12}, the levels of which in milk may be insufficient, or have been depleted by heat treatment (Causeret, 1971). Finally, it is advisable to add more than the recommended doses of fat-soluble vitamins, bearing in mind the relative instability of vitamins A and D.

Corresponding data are not available for the lamb, and recommendations suggested for the calf should thus be applied.

Composition of milk replacers

LIPIDS. Fats that can be utilized are the fatty animal substances (the fat in milk and tallow, and pig fat) and the slightly unsaturated vegetable oils (coconut oil and palm oil). Despite their high digestive utilization, highly unsaturated vegetable or marine oils (maize, sunflower, soybean, fish, etc.) can only be incorporated in large quantities after partial hydrogenation because of their adverse effect on growth and carcass quality. It is better to use mixtures of fats so as to include a wide variety of fatty acids, thus avoiding any digestive or metabolic overload. In particular, the presence of fatty acids with short and medium chains (coconut and palm oils) may have a favourable effect on the animal (Toullec and Mathieu, 1971). The presence of such fatty acids is very useful in the lamb because they are well digested even by animals of low birth weight (Houssin, unpublished results; Theriez *et al.*, 1973) and have a highly favourable effect on growth, health and carcass quality (Aurousseau *et al.*, 1973).

Lipids make up about 28 percent of the dry matter in cow's milk that has 3.5 percent of fat. The use of milk replacers rich in fats (up to 25 percent) seems to be appropriate in the production of low-weight slaughter calves to enable them to reach a sufficient degree of fattening, especially animals of breeds that are late maturing (e.g., the Montbeliarde). However, prolonged intake of these feeds can cause a slowdown in growth and lead to liver disorders, probably as a result of metabolic overload. For these reasons two main methods may be used:

- Provision of a feed for growth rich in protein (24 to 25 percent of digestible proteins) with a moderate lipid content (18 to 20 percent) during the first weeks, followed by a finishing-feed less rich in proteins (20 to 21 percent) and with a higher lipid content (22 to 24 percent), which is gradually substituted for the initial feed;

- Provision of a single feed intermediate between the two preceding feeds (23 to 24 percent proteins, 21 to 23 percent lipids).

As the weight of the calf increases before slaughter, introduction of very high lipid contents in milk replacers becomes less and less justified by technical considerations. For the production of very heavy calves it may even be useful to decrease the amount of lipids at the finishing stage and partly replace them with starchy substances (Thivend, 1976). Feeds for breeding calves should contain 24 to 25 percent of digestible proteins and 18 to 19 percent lipids.

A very high lipid content (30 percent) has an adverse effect on the health and growth of lambs, this being especially marked after weaning — during the fattening period (Molenat and Theriez, 1972). However, too low a lipid content (20 percent) lowers carcass quality with adipose deposits having a high water content and being less firm (Theriez, 1975).

CARBOHYDRATE. The only carbohydrate present in appreciable quantities in cow's milk is lactose (38 percent of dry matter). It is always a large part (38 to 50 percent) of the dry matter included in milk replacers, where it is mainly supplied by skim milk and milk whey and sometimes by whey and milk serum derivatives. Feeding with usual milk replacers, even those with the highest lactose contents, is not likely to involve the intake of excessive amounts of this carbohydrate in view of the animal's large digestive and absorptive capacity. Digestive limits may, however, be reached in the case of very heavy calves. It does not seem advisable, therefore, to replace lipids with lactose in feeds for the finishing period (Thivend, 1978).

All the other alimentary carbohydrates can be used in the young calf if incorporated at a low level (2 to 3 percent of dry matter). Beyond this level sucrose should be excluded together with the derivatives of highly hydrolysed starches, such as soluble dextrines. Raw starch, processed starches, maltose or glucose may be employed interchangeably at a rate of 5 to 7 percent of dry matter. Above this concentration it is recommended that a mixture of these carbohydrates be used; this prevents the accumulation of fermentable substances in the intestine as it is increasingly hydrolysed. This mixture may be introduced at the rate of 8 to 10 percent in feeds given to the calf up to the age of two months. Thereafter this concentration may be doubled or even tripled without any effect on the frequency of diarrhoea. In every case, however, it is necessary to accustom the animals to it gradually (Thivend, 1976).

The starches commonly used in milk replacers are obtained almost entirely from maize, although they may also come from wheat, cassava or potatoes. Most of these products must undergo technological processing (thermal, mechanical or enzymatic) before use. The purpose of this processing is to facilitate the attack of the substrate by the digestive enzymes of the calves and thus increase the digestive utilization of the starch. This is, however, mainly meant to make the substance more soluble and facilitate its maintenance in suspension during the reconstitution of the milk replacer. The finished product is then a mixture of glucose polymers of a wide range of degrees of polymerization. Short-chain molecules with similar characteristics to maltose, highly soluble dextrines, water-insoluble dextrines and chains

TABLE 9. **Examples of milk replacers corresponding to feeding requirements of the pre-ruminant calf. Composition of whole milk**

Type of feed		Start	Growth	Ordinary finishing	Finishing heavy calves	Single	Breeding calf	Whole milk
Constituents (%):								
Spray-dried skim milk [1]		72 (66-72)	65 (60-65)	52 (50-60)	53 (50-60)	60 (60-63)	30 (27-35)	—
Spray-dried milk whey		3.8 (3- 8)	9 (5-10)	16 (6-20)	11 (5-15)	12 (10-15)	29 (20-35)	—
Fat [2]		17 (16-18)	18 (17-19)	22 (21-23)	13 (12-14)	21 (20-22)	18 (18-19)	—
Starchy products		4.5 (2- 5)	6 (2-10)	8 (2-10)	21 (20-25)	5 (2-10)	6 (2-10)	—
Dried milk whey partially delactosed		—	— (0- 2)	— (0- 3)	— (0- 3)	— (0- 2)	2 (0- 4)	—
Soybean cake		—	— (0- 2)	— (0- 3)	— (0- 3)	— (0- 3)	3 (0- 4)	—
Potato protein concentrate		—	— (0- 2)	— (0- 3)	— (0- 3)	— (0- 3)	3 (0- 4)	—
Yeasts or bacteria		—	— (0- 2)	— (0- 3)	— (0- 3)	— (0- 3)	3 (0- 4)	—
Fish protein concentrate		—	— (0- 2)	— (0- 3)	— (0- 3)	— (0- 3)	3 (0- 4)	—
dl-methionine		0.20 (0.18-0.20)	0.18 (0.17-0.18)	0.17 (0.15-0.17)	0.17 (0.15-0.17)	0.17 (0.15-0.17)	0.20 (0.15-0.20)	—
various (minerals, vitamins, antibiotics, milk ferments)		2.5 (2- 3)	1.8 (1- 2)	1.8 (1- 2)	1.8 (1- 2)	1.8 (1- 2)	2.8 (2- 3)	—
Organic constituents (g/kg DM) (1) and apparent DUC (%) (2):								
Organic matter	1	930 (925-935)	930 (925-935)	930 (925-935)	935 (930-940)	930 (925-935)	925 (920-930)	930
	2	96.8	96.7	96.6	95.3	96.5	94.1	97.6
Nitrogenous matter	1	269 (250-280)	256 (250-260)	217 (210-220)	215 (200-220)	241 (240-250)	248 (250-260)	259
	2	94.9	94.9	94.8	92.3	94.9	91.0	95.7
Fats	1	185 (160-190)	195 (185-200)	236 (220-240)	142 (125-145)	226 (210-230)	200 (190-210)	280
	2	94.5	93.7	93.7	93.7	93.7	89.0	97.7
Carbohydrates	1	476 (460-520)	479 (450-530)	477 (465-500)	578 (565-595)	463 (465-485)	477 (400-480)	391
	2	98.8	98.8	98.8	96.8	98.8	97.8	98.8
Mineral constituents (g/kg DM):								
Ash		70-80	65-75	65-75	60-70	65-75	70-80	70
Calcium		13-15	11-12	9-10	8-9	9-10	11-13	10
Phosphorus		8-10	7.5-8.5	7-8	6.5-7.5	7-8	7.5-8.0	7.5
Potassium		12-13	12-13	12-13	11-12	12-13	12-13	12
Sodium		4-5	4-5	4-5	4-5	4-5	4-5	4
Magnesium		1.4-1.6	1.4-1.6	1.4-1.6	1.4-1.6	1.4-1.6	1.4-1.6	1
Chlorine		8-10	8-12	8-12	8-12	8-12	8-12	8.5
Iron		0.025-0.050	0.015-0.020	0.010-0.015	0.010-0.015	0.010-0.015	0.040-0.050	0.003
Energy (Mcal/kg DM):								
Gross [3]		5.07	5.12	5.27	4.80	5.26	5.12	5.56
Digestible		4.88	4.91	5.05	4.55	5.04	4.75	5.42
Metabolizable [4]		4.70	4.74	4.87	4.39	4.86	4.58	5.23

NOTE: — = negligible; DUC = digestive utilization coefficient; DM = dry matter. Figures given in brackets express ranges for commercial products.

[1] Since 15 April 1976 dried skim milk must make up at least 60% of feed formula to enjoy the denaturation bonus within the European Economic Community. — [2] Mixture of tallow and coconut oil (50 and 50% in starte feeds, 75 and 25% in other feeds). — [3] Energy values used (kcal/g of dry product), according to Blaxter (1962): tallow 9.45, copra oil 9.03, milk fat 9.24, lactose 3.85, starchy products 4.01, proteins 5.65. — [4] Metabolizable energy/digestible energy = 0.965 (Vermorel et al., 1974; Liebenberg and Van der Merwe, 1974).

of unchanged starch are found. The proportion of these different constituent elements varies according to the type of processing undergone by the initial starch. These starchy substances are essentially composed of glucose molecules (99 percent) and contain very small quantities of minerals. Their iron content may reach 20 to 30 mg/kg with certain types of technological processing.

The use of carbohydrates other than lactose in milk replacers for lambs is not very widespread because they are of little economic interest in Europe. Moreover, sucrose can only be used in small amounts because of its strong diarrhoetic effect. However, starchy products can be a source of energy that is well utilized by the young lamb. Soliman *et al.* (unpublished) have shown that the replacement of lactose (27 percent) in milk replacers with starchy products (25 percent) causes no change in the performance of lambs that are fed this diet from the age of one week. A larger quantity of starchy products (up to 40 percent of dry matter) may perhaps be used if lambs are fed frequently.

PROTEINS. In order to introduce them into milk replacers, protein sources should first of all show a satisfactory balance of essential and less-essential amino acids, or should be easy to supplement to give such a balance. In addition they must be appetizing, soluble or easily kept in suspension, devoid of constituents that are hard to digest (complex carbohydrates) or undesirable, and, finally, in the case

of milk replacers for slaughter calves, they should have a low iron content.

At the present stage of protein extraction and processing, dried skim milk is still the product that is best utilized and at the same time is included in the sources of nitrogenized substances that can be introduced in milk replacers. It is nonetheless important not to submit it to excessive heat treatment, especially when the feed is meant for very young animals. Other protein sources (milk whey, yeasts, soybeans, fish, potatoes, etc.) give good results with slaughter calves and lambs; however, they usually have a depressing effect that decreases with age when the rate of substitution is high (25 to 50 percent proteins). Many of them are too rich in iron to produce white meat when introduced at high levels. This shortcoming does not exist in the case of breeding animals; it can be overcome in the case of slaughter veal by adding an iron chelating agent, provided it is harmless to the animal and the consumer. Moreover, it appears that iron availability varies according to the source of the protein (Van Weerden *et al.*, 1973).

Characteristics of milk and the main types of milk replacers

Cow's milk is a highly digestible food, very rich in energy. However, its composition, especially its lipid content, may vary widely according to the stage of lactation, the cow and its feeding, the season, the day and the degree to which the udder is emptied (Alais, 1975).

The average percentage of skim milk powder in milk replacers fed to calves marketed in France (apart from "milkless" feeds) was 70 percent in 1962. It was still as high as 62 percent at the beginning of 1971, but fell rapidly to only 53 percent in 1972 owing to the relative scarcity of dried milk in 1972. However, these average percentages differed according to formula, depending on whether they were intended for breeding calves or for slaughter calves during their growth or finishing stages. The principal formulae are shown in Table 9.

However, within the European Economic Community since April 1976, in order to claim the denaturalization bonus, dried milk has to make up at least 60 percent of the feed formula. Average rates of inclusion in milk replacers for calves in France in 1977 were 62, 20 and 12 percent for dried skim milk, fats and milk whey powder respectively.

Currently in France the feeds most widely employed for calves are of the growth, finishing and single types. Starting-off feeds generally have a high content of high-quality dried skim milk as well as a moderate content of substances rich in coconut oil. These feeds are occasionally enriched with trace elements and various additives (vitamins, milk ferments, etc.) but, despite their merits when enriched, they are not much used because of their high cost. Feeds for breeding calves are usually the only ones containing high proportions of substitute proteins. Nonetheless, the best feeds for breeding calves are those of the growth or single type for slaughter calves. With the lamb only one type of feed is used at present (25 percent protein and 25 percent lipid); coconut oil is widely used because of the advantages it offers, in spite of its price sometimes being high.

Conclusion

Milk replacers in current use are generally well utilized by young animals. Nevertheless their efficacy could be increased through a better adjustment of their compositions to the requirements of the calf, which vary considerably according to the age of the animal and its end use (i e., as a breeding calf, light or heavy slaughter calf, etc.). Thus, a more judicious choice of energy sources could work in favour of increased protein formation and better control of the development of fat reserves in slaughter calves killed at a heavy weight. The advantage of including replacement proteins will depend upon their price, advances in the technology of their preparation and the availability of dried skim milk. ■

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Feedstuffs: Current Situation and Short-Term Outlook[1]

World feedstuff demand reached a new high point in 1979. The rapid expansion in the use of concentrates continued in the United States and Japan, and in many developing countries, including Korea, Mexico, and several members of the OPEC group. In the United States the use of feed-grains increased by an estimated 10 percent over the previous year.

World poultry and pig meat production rose at estimated annual rates of 5.7 and 3.6 percent respectively, resulting in increased demand for coarse grains and wheat used as feed, as well as non-grain concentrate ingredients (such as milling by-products, cassava, and feed pulps), and oilseed cakes and meals. High beef and veal prices generated good demand for cattle finishing rations of all kinds, including grains, silage and processed fodder (chiefly hay, pellets and by-product meals). The demand for concentrates and processed fodder was also strengthened by the severity of the 1978/79 winter in most parts of the Northern Hemisphere, and by the large-scale conversion of European dairy herds to breeds with high yield response to concentrate feeding.

Other major factors behind the increased demand for feed concentrates were the rising meat/feed price ratios which, until early 1979, favoured pig and poultry farmers in most countries outside the EEC, and the considerable improvement in feed utilization (i.e., better feed/meat and feed/egg conversion ratios) in the commercial pig and poultry sectors.

In the EEC and in other European countries with similar feed pricing policies the high cost of grains continued to encourage the greater use of oilseed cakes and meals, and of non-grain concentrates such as milling by-products, processed roots and tubers (chiefly cassava) and other feeds which are not subject to high import levies. High grain prices in western Europe also continued to promote the greater consumption of annual green fodder crops (chiefly green maize) and of silages.

In eastern Europe the feed use of potatoes and of green fodder increased, and in the USSR the use of treated fodder (straw, vines of legumes, reeds and stalks) expanded.

Some of the major factors likely to influence world feedstuff demand in 1980 are as follows:

- As the current beef cycles in the United States (the largest beef producing country) and Australia (the largest beef exporting country) approach their low points, more cows and heifers will be retained by farmers for breeding in order to rebuild their herds. This is likely to lead to more cattle and calves on pasture and fodder in all major beef producing coun-

[1] As of 21 January 1980.

Production estimates for pig meat and poultry meat in selected areas

Thousand tons

Area	Pig meat			Poultry meat		
	1978	1979 Preliminary	1980 Forecast	1978	1979 Preliminary	1980 Forecast
Brazil	850	850	875	858	927	1 000
Canada	620	742	772	460	528	550
China	14 064	14 276	14 500	3 340	3 437	3 500
EEC	9 328	9 775	9 800	3 583	3 757	3 800
Japan	1 284	1 400	1 470	1 027	1 088	1 125
United States	6 075	6 869	7 500	5 896	6 499	6 700
USSR	5 302	5 200	n.a.	1 902	2 100	n.a.
Estimated world total	49 438	51 214	52 000	26 127	27 616	28 200

NOTE: n.a. = not available.

Source: World Meat Situation and Outlook, FAO, Document CCP: ME 80/Misc. 1, January 1980.

tries and to cattle feeding using somewhat less concentrate feed than a year before.

- The severe 1978/79 winter in parts of the Northern Hemisphere led to the heavier feeding of dairy cattle and this, in turn, resulted in a reduction in stocks of hay and other forage in many countries. Although the overall forage situation improved in the second half of 1979, when United States hay production reached a new record, stocks in the USSR and much of eastern Europe were reported to be low at the end of 1979. Should the output of the 1980 spring pastures and fodder crops (particularly green oats and rye) be low, demand for dairy concentrates could increase.

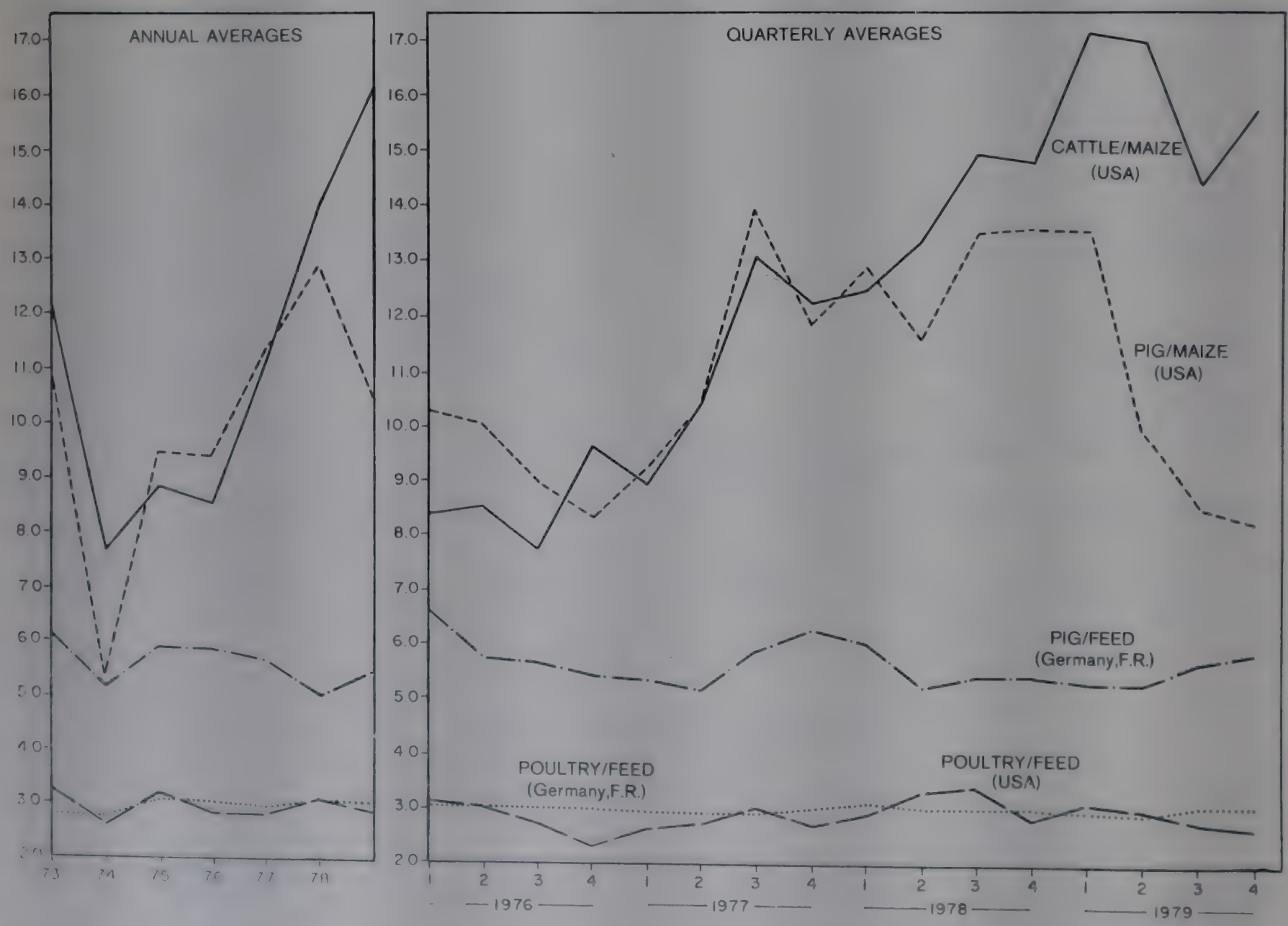
- During 1980 the output of pig and poultry meat is expected to continue to increase moderately in many areas, particularly in the United States (see Table). However, the 1979 increases in international coarse grain prices combined with lower pork and static poultry-meat prices, resulted in a sharp downturn of livestock/feed price ratios in 1979 (see chart), and this is likely to slow down pig and poultry production and the demand for feed grains toward the end of 1980.

- A substantial drawdown of grain stocks is expected to take place in the USSR following the poor grain and fodder harvests of 1979.

- The rapid growth in demand for feed concentrates based chiefly on feed grains is likely to continue in a number of oil-exporting countries, and in several non-oil-exporting countries, in Latin America, the Near East and the Far East.

- In most developing countries, where over three quarters of the commercially mixed food is reported to be fed to poultry, demand is expected to continue to rise in 1980. Demand for mixed feed concentrates for supplementary feeding for milk production is also expected to continue to increase.

On balance, current indications are that world demand for feed concentrates will not rise as fast in 1980 as it did in 1979. Domestic feed grain supplies in such major consuming areas as Canada, eastern Europe, the USSR and western Europe will be smaller, and higher prices for feed grains and the resulting lower feed/poultry meat and feed/pig meat price ratios are likely to act as a deterrent to increased pig and poultry production in the United States. Demand may also be limited by the unfavourable economic conditions in the United States and several other devel-



SOURCE: COMMODITIES AND TRADE DIVISION, FAO.

Livestock/feed price ratios: these show the number of kilograms of feed that one kilogram of slaughter cattle, or pig, or poultry will buy.

oped countries, which could bring about a slower rise in per caput meat consumption. However, since fodder stocks are only modest in Europe and are low in the USSR, and because feedgrain stocks will be reduced during the 1979/80 season in the USSR if the 1979/80 Northern Hemisphere winter is severe, a tight supply/demand balance would probably result, which would put upward pressure on feed grain prices in 1980.

International course in tropical animal production

The above course is to be held at the Netherlands National Agricultural College, Deventer, each calendar year commencing in mid-August 1980. The course offers practical and theoretical tuition on a wide range of animal husbandry subjects. It is designed to benefit especially extension workers and those who are at present engaged on animal husbandry projects. Its aim is to refresh the student's existing knowledge and up-date this with information on current practices and methods.

Intending applicants should be fully conversant with the English language, in which the course will be held, should possess at least a certificate in agriculture and should have had experience in animal husbandry. Applications should be submitted before 1 May 1980. Further inquiries should be directed to the Principal of the National Agricultural College, PO Box 7, Deventer, the Netherlands.

Ninth international congress on animal reproduction and artificial insemination

The above congress is to be held in Madrid, Spain, from 16 to 20 June 1980. There will be three plenary sessions: physiology of reproduction; artificial insemination; and pathology of reproduction. Fifteen special problems have been selected for round-table discussion. In addition, symposia on nine selected subjects and a number of poster sessions will be held.

Applications for hotel accommodation and post-congress tours should be sent before 1 March 1980 to Compañía Hispanoamericana de Turismo, Edificio España, Madrid-3, Spain. General inquiries regarding the congress should be addressed to the General Secretariat, Prof. Dr T. Pérez García, INIA, CRIDA-06, Departamento de Reproducción Animal, Avda de Puerta de Hierro, s/n, Madrid-3, Spain (tel. 449 11 76).

World Congress on Sheep and Beef Cattle Breeding

The New Zealand Federation of Livestock Breeding Goups, with other breeders and scientists, is organizing and supporting the above Congress to be held in November 1980. The Congress is for those interested in the genetic improvement of sheep and beef cattle. It will be centred on a technical session to be held at Massey University on the North Island and a second session at Christchurch on the South Island that will be orientated towards modern livestock breeding practices. Programmes are being drawn up to include speakers of international scientific standing and livestock breeders from various countries.

Tours both before and during the Congress will form an integral part of it and will give an unrivalled opportunity for seeing something of New Zealand's great livestock industry, which is essentially based on pastures, and of its scenic beauty.

The Congress Organizer is Mr R.A. Barton, Massey University, Palmerston North, New Zealand, to whom further inquiries (other than in connection with travel arrangements) should be addressed. Bookings for internal travel, accommodation and tours can be arranged through Travel Manager, Dalgety Travel, PO Box 643, Palmerston North, New Zealand.

International Foundation for Science (IFS)

A summary of a recently published report of a Workshop on Rabbit Husbandry in Africa organized by IFS is given on p. 46. This organization has been created to support young, promising scientists and technologists in their research work in developing countries, but the valuable work it is doing is not yet widely known.

The International Foundation for Science, founded in 1972, is a non-governmental organization based on scientific academies and research councils in 44 countries, two thirds of which are in developing countries and one third in industrial parts of the world. The Foundation is governed by an international board of trustees. The secretariat is located in Stockholm, Sweden.

Research grants. Support to research is provided in the form of grants, scientific advice and arrangements for international contacts.

Criteria for a research grant are the scientific quality and promise of the proposed research project and its relevance to the needs of the country concerned. To be eligible for a grant an applicant must be a native of, and carry out the research in, a developing country.

The grants are given to individual scientists or to a group of scientists and are primarily intended to provide equipment, expendable supplies and some technical assistance for a specific project. The grants are fairly small; they do not normally exceed US$10 000, and average between US$6 000 and 6 500. A grant can usually be renewable up to four times.

The Foundation's support is for the time being limited to seven priority areas, which have been selected after thorough discussions with scientific councils and academies in developing countries. The priority areas are: aquaculture; animal production; vegetables, oilseeds and fruits; mycorrhiza and afforestation problems; fermentation; methods for food preparation; natural products and rural technology.

Among scientific subjects related to animal production at present being supported are: development of new feed resources and methods for dry season feeding; introduction of improved animal production systems; research on neglected animal species and collection of basic information on performance of local breeds and the prolongation of the storage life of animal products.

Workshops. Another important kind of support, complementary to the financial, is the arrangement of workshops for IFS grantees working on related problems. Scientists in developing countries sometimes have good contacts with research institutes in industrialized countries, but may have no or very few contacts with colleagues working under similar conditions. Regional workshops on a particular subject are one way to break through this isolation.

IFS has many activities under way related to small domestic animals, of which the Workshop on Rabbit Husbandry in Africa described in the following note is one example. There are, however, other projects that IFS is assisting, such as one in Palawan, the Philippines, where protein for pig and poultry feeds is obtained from snails; one in the Andes on guinea-pig production, where new concepts have been introduced

and in which the production and financial return are astonishing; and several in West Africa on the domestication of cane rats.

This line of activity is also being followed up by initial attempts to create "affinity groups" of IFS grantees with different specializations within a wider scientific field. A closer contact between such scientists should enable a more rational planning of research efforts.

Scientific advisers. Another asset of the Foundation is its international panel of experienced scientists within the different priority areas. These advisers assist the Foundation with the evaluation of grant applications, and with the overall assessment of the scientific quality of the supported projects. In many cases they also provide direct assistance to the grantees through personal visits or by correspondence.

Further information. The Foundation's working languages are English and French, and inquiries are welcome in either of these languages.

Information material and application forms are available from the IFS Secretariat, Sibyllegatan 47, S-114 42 Stockholm, Sweden.

Workshop on rabbit husbandry in Africa

In December 1978 the Tanzania National Scientific Research Council, the University of Dar es-Salaam and the International Foundation for Science (IFS) jointly organized the above workshop at Morogoro, Tanzania. The IFS has published in its Provisional Report No. 4 a most stimulating and valuable account of the proceedings of the workshop. The three sponsoring bodies are to be complimented on convening this first scientific meeting on rabbit husbandry for the African continent.

Attended by delegates from Ghana, Kenya, Malawi, Mauritius, Mozambique, the Sudan, Tanzania, Togo and Zambia and with participants from the Federal Republic of Germany, Sweden and the United Kingdom (representing a broad spectrum of farmers, extension workers and scientists with a wide range of experience and viewpoints), the workshop heard a number of excellent papers in which experiences in developing rabbit production in the various countries represented were described in considerable detail. These papers, and the discussions that followed, provide a valuable review of rabbit husbandry, production and health in tropical countries in general and in developing African countries in particular on which little has so far been published.

The workshop recorded a number of important recommendations including ones emphasizing the need for more research on all aspects of rabbit husbandry — in particular, on feeding and nutrition, especially the investigation of locally available tropical feeds (including herbage species and agro-industrial by-products) and the major diseases of rabbits occurring in Africa. The need for breeding stations, the promotion of rabbit meat as a valuable source of animal protein and of rabbit husbandry in its capacity to create employment, the need for more studies dealing with extension, management and research on rabbits and for more organization of interested producers in associations, were also the basis of a number of important recommendations.

Interest in rabbits as meat producers is increasing rapidly in a number of countries that have difficulty in providing their populations with adequate protein without incurring adverse balances of trade.

Even in countries apparently well stocked with domestic livestock, interest in rabbits as a cheap source of protein is developing. The livestock of such countries may not be evenly distributed throughout the country and there may be meat-deficient areas as well as meat-surplus areas. Distribution and storage systems for meat are expensive and complicated and, in any case, poorer sections of the community may not be able to afford the meat available. In many countries there are often abundant supplies of crop and animal by-products and agro-industrial by-products going to waste that can be utilized by rabbits.

There are, of course, problems involved in developing rabbit production, such as the need to train personnel, the lack of good breeding animals adapted to local environmental conditions and the general lack of the research and investigation necessary to provide sound guidance to extension workers and promoters of rabbit production.

The Report of the Workshop on Rabbit Husbandry, briefly reviewed above, represents a major step forward in laying the foundations for what could be a valuable animal industry in many developing countries, providing a cheap source of essential protein to populations in meat-deficient areas.

Copies of the Report are available free of charge from the International Foundation for Science, Sibyllegatan 47, S-114 42 Stockholm, Sweden.

Articles on various aspects of rabbit husbandry, production and health will appear in future issues of this journal.

FAO/SIDA/Government of India Seminar on Reproduction and Artificial Insemination of Buffaloes

In December 1978 a seminar on reproduction and artificial insemination of buffaloes was held jointly by FAO/SIDA and the Government of India at Karnal, Haryana, India, as part of the wide-ranging FAO Programme for Artificial Insemination and Breeding Development, organized under a Trust Fund established by the Government of Sweden. The purpose of the seminar was to put artificial insemination (AI) in its correct perspective in relation to other measures for improving buffalo production.

Many recognized authorities from 19 collaborating countries took full advantage of what was a unique opportunity for exchanging information and views and witnessing a number of practical demonstrations of advanced techniques. The full proceedings of the seminar, including the text of the working papers, will be published by the National Dairy Research Institute of Karnal, India.

Because of the lack of information on the growth, milk production, meat potential and work capacity of the numerous breeds of swamp and river buffaloes the seminar made detailed recommendations concerning the records, measurements, other data and information needed to be obtained and kept, from both large buffalo herds and small-farm buffaloes, on growth, fecundity, lactation, meat production, work capacity, artificial insemination, and progeny and performance testing.

A recommendation emphasized the need for buffalo progeny testing in order to provide the high quality sires required in all countries and for performance testing of the major buffalo breeds as part of an international effort to determine the relative genetic merits of the different breeds and strains of buffaloes. Considerable emphasis was placed on the importance of improved management and nutrition practices and of adequate health control measures to ensure that genetic improvement was not impeded by inadequacies in feeding,

housing and handling or by the presence of deficiencies, diseases or pathological abnormalities.

Because relatively little research has so far been devoted to the many problems arising in buffalo reproduction, the seminar recommended the lines of research that need to be followed and the fundamental investigative work that needs to be started immediately. The hormonal status, synchronization of oestrus, physiopathological problems, seasonal fertility and effects of levels of nutrition on reproductive capacity were discussed at length and formed the basis of a number of important recommendations.

As regards semen production and processing for AI, the seminar devoted much attention to buffalo spermatozoan metabolism, the biochemical and physiochemical factors involved in spermatozoal activity, the screening of semen for freezing and the behaviour of spermatozoa during freezing and thawing.

In the discussion on nutrition, management and health, considerable attention was devoted to the growth, rearing, management and housing of the buffalo calf and a number of recommendations concerning these very important subjects were made.

With the upsurge of international interest in the productive potential of the water buffalo, the wide circulation of results of research work and the findings of specialist workers in buffalo production is necessary. The part that storage and retrieval capacity of computer systems could play in this context was strongly emphasized by the seminar.

PUBLICATIONS

New international journal: Agricultural Wastes

Four quarterly issues per volume (16.5 × 24 cm) of 320 pages.

The Applied Science Publishers Ltd, Ripple Road, Barking, Essex, UK, have recently published the first issue of a new journal, *Agricultural Wastes — an international journal*. The editors are Peter Hobson, Head, Microbiology Department, Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB, Scotland, and E. Paul Taiganides, Manager, UNDP/FAO Project SIN/74/006, Primary Production Department, 17 km Sembawang Road, Singapore 26.

This new journal provides a forum for original papers concerned with all aspects of the management and treatment of agricultural wastes, i.e., not only the excreta of animals and birds, but also crop and forest residues, agricultural-chemical residues, wastes from the processing of animal and vegetable matter on farm or in factory, and wastewaters from food-processing plants.

The Journal represents a major step forward in making available, on a worldwide basis, new scientific and engineering knowledge on the management and utilization of wastes. It should be a useful source of information to those interested particularly in the techniques and processes involved in animal wastes management and in the recycling of animal excreta and utilization of agricultural and agro-industrial by-products in animal feeding.

M.C.

Studies on the control of rinderpest in Nigeria

M.R. FELTON and P.R. ELLIS, University of Reading, Veterinary Epidemiology and Economics Research Unit, Department of Agriculture and Horticulture, Study No. 23. 1978. Price: £2.50.

The Veterinary Epidemiology and Economics Research Unit in the Department of Agriculture and Horticulture, University of Reading, was created in order to foster interdisciplinary cooperation in the field of animal health. Under the leadership of Mr P.R. Ellis, the team is currently made up of four veterinarians, two economists, an agricultural scientist, an animal production specialist, a computer programmer, and ancillary staff.

This study was undertaken as part of a cooperative research programme on veterinary epidemiology and economics with the Federal Livestock Department, Federal Ministry of Agriculture and Rural Development, Nigeria, and supported by the Natural Resources Research Department of the Ministry of Overseas Development, United Kingdom.

The authors briefly review the history of rinderpest in Asia, Europe and Africa and describe in some depth the epidemiology of the disease. The Nigerian Control Programme is described in detail and the costs are well defined, with the objective of determining the benefit/cost ratio for rinderpest control in Nigeria. The benefits are based on reduced mortality and reproductive losses as a result of controlling the disease. It was observed that rinderpest control changed the age structure and average size of Nigerian herds.

This study is one of the first well-organized benefit/cost analyses of livestock disease control in a developing country.

W.R.M.C.

Leaf protein and other aspects of fodder fractionation

By N.W. PIRIE. 1978. Cambridge University Press. 183 pages. Price: £8.00

The author, who has been actively involved in the development of fodder fractionation techniques, describes the methods of separating protein from leafy crops. One chapter gives an account of the nutritive value and the potential use of the various products of fractionation as animal feed. Another chapter deals with human utilization. In the last chapter the author discusses fodder fractionation in practice.

The numerous references and the informative account will be of interest to agricultural research workers and students as well as those interested in nutrition and the developing world.

M.C.

Feeds and nutrition

By M.E. ENSMINGER and C.G. OLENTINE JR. The Ensminger Publishing Company, 3699 East Sierra Avenue, Clovis, California, 93612, USA. 1978. 1 417 pages (complete edition); 824 pages (abridged).

This comprehensive textbook covers all aspects of feeds and nutrition of farm animals. The presentation is based on firm scientific grounds, confirmed by recent research findings. The main feature of this book, however, is the good overview that it provides of practical problems and of the application of knowledge to various practical situations. The projection of ideas on future developments in livestock production is also worth noting.

The contents are divided into three main parts — nutrition, feeds and feeding. In addition there is a glossary of nutrition terms and feedstuffs, tables of the composition of feeds and an appendix (weights and measures, animal units). Each of the 28 chapters is followed by questions for study and discussion. The abridged edition has basically the same structure as the complete one but it eliminates much of the technical matter and accentuates the aspects of application.

In the first part, "Nutrition", the first chapter ("Feeds vs Foods") deals with the role of animal agriculture in supplying food to man, focusing discussion on the points that are, and that will in the future, be central to any consideration of the contribution of animals to world food supply.

In the next three chapters the main features of digestion, absorption and metabolism are studied and well illustrated with diagrams, pictures and tables. A special chapter is devoted to nutritional diseases, with a table giving a short description of the most common nutritional diseases and their causes, symptoms, treatment and prevention.

The second part ("Feeds") gives a description of all the feedstuffs used in animal feeding, including by-products and crop residues. The nutritive and other characteristics affecting the utilization of the various feeds in practical feeding systems and situations are described. The chapter entitled "Feed Supplements — Additives — Implants" gives a review of the mode of action and effects of various additives and supplements used in animal feeding. Feed processing and feed evaluation, important items in present day livestock husbandry, are well covered. These chapters are followed by a chapter on buying feeds, commercial feeds, and feed laws.

The third main part of the book ("Feeding") deals with the following classes of farm animals: beef cattle, dairy cattle, swine, poultry, horses, rabbits, mink and fish. Before concentrating on each category of animal production an overall review of animal behaviour and environmental factors is given.

National Research Council (NRC) feeding standards have been used for each class of farm animal. In the feed tables TDN, DE, ME, NE for maintenance and gain and NE for lactation have been given for each feed. The general principles of ratio formulation are introduced after presenting the feeding standards. In the chapters dealing with the feeding of each class of farm animal, the nutritive needs are discussed in detail and requirements for each nutrient are given in table form. Thereafter, the use of various feeds has been described in more practical terms, paying attention to the formulation of the ration in different practical situations.

The book will find users among all categories of people dealing with livestock production. It provides students and research workers, as well as advisory staff and farmers, with the latest available information in an easily understandable form.

EP

Bibliography of the domestic rabbit

Cooperative Extension Service Colorado State University, Fort Collins, USA. Bulletin 481a. 1979.

Rabbit production is emerging as a new, important field of animal husbandry not only in developing countries but also in developed countries. The current issue of this journal, for example, contains a review of the report of the first scientific meeting on rabbit husbandry held on the African continent.

This bibliography was first published in 1972; since then there has been a substantial increase in information available on the rabbit.

D.E.F.

Corrigendum

World Animal Review 31, 1979. Chilling and freezing of meat in developing countries.

Page 31, column 3, line 16: *For* 14-10°C *read* 14-16°C

Page 34, Table 4: The maximum storage period for pork (omitted) is six months

COMMENT

(Continued from front cover)

recent meeting (1979) in Japan of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO), with participation from the major countries of the region, recommended that, as a matter of priority, a cooperative project should be undertaken for the evaluation of the genetic merit of the various buffalo strains and breeds.

The TAC, following its 1976 meeting, secured the services of a consultant who recommended that, of several possible alternative arrangements for implementing a comprehensive research programme, the establishment of an international cooperative network of participating national institutions with a suitable means of coordination was the most viable one in technical and economic terms.

An international research programme of this kind would need to be established in stages beginning with the identification of a small number of national institutions where the most progress had been achieved. These centres could then form the basis for a network of national research institutions cooperating with each other in a framework designed to facilitate the maximum coordination of research and research training. FAO has now approached a number of potential funding agencies to make this possible.

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